THE GRADUATE'S PLACE IN PRODUCTION.

Paper presented to the Institution, Birmingham Section, by R. H. Youngash, M.I.P.E.

I FEEL I ought to define the title of this paper, in order to remove any possible doubts or ambiguity, as meaning "The Graduate's place in *industry*," and it is in this sense I propose to address you to-night.

The Council of the Institution of Production Engineers have always considered the question of graduate membership to be one of considerable import, and ever since the formation of the first junior section, which, no doubt you will remember, was here in Birmingham, great care has been taken to ensure that the young men admitted shall be of a very high standard. The graduateship examination of the Institution has changed the curriculum of our technical school training to such an extent, that the better ones are now offering students a course in production engineering of a totally different nature from that of a few years ago, a course which not only enables those who take it to sit for the entrance examination of the Institution, but is producing a generation of young men whose outlook on modern engineering problems is in keeping with present-day conditions.

You will have heard, or read, our lectures on "What a Graduate should know" and will be familiar with the steps that have been taken to prove, by examination, that aspirants have the necessary qualifications before admission to membership.

The Council of the Institution expressed a desire that Sections should deal with this problem in three stages; first the training of the student, and his development up to the point where he may become a member, and second what he is likely to be and to do during the period he is qualifying for a higher grade of membership. The last stage, "The Graduate and management," will be dealt with later.

What then is the graduate's place in industry?

We must remember that when admitted as graduates these young men have reached the age which marks the attainment of manhood; they are assuming the responsibilities of taking part in the affairs of life in their own right, and in directions of their own choice, but, before we can assign them a definite place in industry, we must examine, very briefly, just what they are, or, shall I say what they are *likely* to be.

December 15, 1937 (Vol XVII, No. 3, March, 1938).

The rules of the Institution provide that graduates shall be over 21 and under 30 years of age. This covers the most vital period of a man's life, as during that time the moulding of his character is completed, his ideals are consciously, or unconsciously, finally fixed, and this combined with the results of the training given and received during previous years, crystalises itself into THE MAN, immature, not fully developed, but the one for whom this paper is written. But the whole problem is extremely complicated, because during the rather long period of graduateship many changes take place, and the man of thirty, now qualified for associate membership, is vastly different from the undeveloped graduate on his admission.

And so we shall find our newly elected graduate is equipped with a considerable amount of scientific and technical knowledge, and a fair degree of practical experience, and that he has had a good general education. He probably holds a position as a minor executive, he is full of energy and enthusiasm, boundless faith in his own abilities, and determined not only to carve out a niche for himself, but also to right the wrongs of society in general. There will inevitably be difficulties and obstacles in his way; he will feel there is not a proper appreciation, on the part of other people, of the wonderful abilities with which providence has seen fit to equip him, the particular job for which he thinks he is best fitted is already filled by someone else, and, of course, there are the old fogies. In these times there ought to be some way of dealing with them, compulsory retirements with pensions (if possible), perhaps the lethal chamber, but he is sure there ought to be some humane way of getting the road cleared for the younger generation.

This is, of course, what one should expect to find. Physical training will have developed a sound body, and scholastic and technical training will have developed the mind to a point where the urge to embark on some creative work is of paramount importance, and to the young man at this stage, no effort is too great and no problem too large, but like a young colt he has yet to be broken in, and while those who have to perform this, sometimes thankless, task, should take every possible care that it is done gently and carefully, the colt is the one who ultimately benefits most from the process.

It was, doubtless, with this end in view that the Council decided to have the whole question of graduates reviewed, in order that they may have the benefit of advice as to the best way of progressing through the graduate stage, and of becoming not only useful members of the Institution, but also of the profession which they have elected to follow.

Mechanical engineers may be divided into two main categories, first the constructive type, and second the administrative type. The former are most suitable for positions as designers, draughts-

men, estimators, and such like. They are usually studious, reserved, and of a somewhat nervous disposition, while the latter are more boisterous in their manner, aggressive in their disposition and generally do better in positions of a supervisory nature.

There is a very clearly marked tendency for individuals to separate into one or the other of these two groups *of their own volition*, and it should be observed that while their relative capacities may, and probably will, be substantially the same, so that the one may undertake the duties of the other with some measure of success, too often the result is a square peg in a round hole. The most successful will be those in which the best combination of these attributes are to be found.

There will, of course, be many sub-divisions of these two main groups, but in each group probably not more than 10% can, by their own natural limitation, ever become men of outstanding importance. A large proportion will be very little more than " hewers of wood and drawers of water," but it should be observed that the sum total of the efforts, firstly in better training, and secondly the spreading of knowledge by means of Institutions such as ours, must result in higher, and still higher standard of competence generally, and by a smaller margin of difference between the grades.

This rough classification indicates the type of work for which the individual is most suitable. Each will experience similar difficulties in making progress, and we may reasonably inquire what are the factors likely to influence the direction a graduate will take. It is perhaps a little trite to quote the well worn phrase, " Circumstances alter cases," but so much depends on matters not entirely under the control of the individual, as well as those he can control, that I hope I may be forgiven for using it.

I suppose it will be taken for granted that he should be healthy ; probably this point will receive very little consideration, although if any known weakness is present it certainly ought not to be ignored, and efforts should be made to avoid employment under conditions which may lead to complications later on. Should the individual live in a small town, remote from the larger industrial centres, his chances of obtaining suitable employment are definitely less than one not so situated, particularly if his financial position is such that he must depend entirely on his own efforts. He may decide to specialise as (say) a jig and tool draughtsman and find, at a later stage, that he is not suitable for work of this nature ; this will involve changing his line of action and may prejudice his chances. He may assume domestic responsibilities, a wife and perhaps a family ; this will restrict his freedom of choice to some extent, as he invariably becomes more fixed and less mobile under those conditions (personally, however, I believe that these responsibilities act as a useful spur to the ambitious in most cases). The formation of bad

habits may be a very potent factor in retarding his progress, because of their effect, not only on his work, but also in the development of his character. His personality will play a big part in his advancement. A quarrelsome disposition, being too aggressive, especially in his earlier years, an inclination to sulkiness, carelessness in speech, slovenly dress, untidy work, too frequent use of the first personal pronoun, unwillingness to admit mistakes, all these, and many other characteristics which go to make up one's personality, are bound to have quite marked influence when promotion is under consideration.

Another point to be remembered is the limitations imposed by natural ability, and this is the factor that determines which of the two groups I have already mentioned, as the constructive and the administrative types, the individual belongs to. It seems to me to be highly important that he should be placed in the appropriate class as early as possible.

This leads to the observation that it would be as well for a graduate early in his career to submit himself to a rather searching examination, in order to arrive, as far as possible, at some conclusion as to exactly what nature of work he is best fitted for, and for this examination he would be well advised to solicit the help of men of mature experience. It may, of course, be argued that this should have been settled during his earlier training period, but owing to the degree of specialisation required to-day, in my opinion, it is better to defer this until, at any rate, the age of admission to the Institution, so that he will not place too high a valuation on what he would *like* to be, as distinct from what he is best fitted for.

Having settled which particular class of work is most suitable, and having secured an appointment that offers possibilities in the right direction, our graduate may be said to be really starting on his career, but he is lacking in one thing, *experience*. This is the most important lesson yet to be learned, and it is not too much to say that it is a lesson that is never completed by any mortal; but some measure of experience must be obtained if progress is to be made. A glance at a dictionary will show many shades of meaning and application of the word, but it is in the broadest sense we must use it to-night, and perhaps more particularly in its application to human nature, because, after all, a man in an executive position has a far greater problem in men than in materials, though in saying this I do not intend to imply that materials are of no importance; but as a man progresses up to the higher positions so the necessity for some knowledge and understanding of the psychology of mankind increases, and the ability to direct the activities of others becomes more and more essential. This qualification can only be obtained by experience, although we know that some have natural abilities as leaders, more marked than others; but experience is the

essential thing, in fact, *Gothe* has it that "*experience is the only genuine knowledge*," and the acquisition of this attribute of human experience is vitally important to our graduate as he passes on from stage to stage through the intervening years between graduateship and associate membership.

There are, of course, many directions in which experience may be obtained, and many different kinds of experience. I shall refer to one aspect of the matter particularly, because it is rather important, although perhaps a little narrow. There are few fixed rules for the manufacture of engineering products. The problems to be solved are approached in different ways, most of them having the virtue that they arrive at a satisfactory solution, so that the opportunity to examine how they are solved by different people offers to the graduate a means of acquiring experience by changing his employment. How often this should be done is a question that will provoke many differing opinions and I feel it is impossible to do more than offer general advice, and even this will always be open to objection under some circumstances.

I believe that it is advisable for a young man to change his employment every three or four years until he is (say) thirty years of age, his mental outlook will be considerably broadened as a result, and his wider experience will make him more valuable. There will no doubt be many difficulties due to reasons outside their own control. There is always the possibility that a periodic reduction in the demand for engineering products will seriously restrict the opportunities of a group of young men for a number of years. Others will lack the courage to break away from their present association. The feeling of having burnt one's boats and embarked upon an entirely new venture produces in some à condition of exhilaration and in others abject depression, but the determination to succeed will quickly overcome this disability and leave the individual better for the experience.

Others may obtain a position which offers chances of advancement in rapid sequence, and he may ultimately find himself in the highest position available. This will not be, however, an unmixed blessing, as "one shop" men are usually insular and narrow, and they certainly will be at a disadvantage if they suffer reverses at (say) middle age.

But, of course, it will be realised that experience is necessary in many other directions as well as the mechanical and technical experience to be obtained by changing one's appointment, particularly those which develop the mind, broaden the outlook on life in general, and ultimately create what we usually describe as character.

It should also be borne in mind that to be of service, experience must be of the right nature, and so far as circumstances will permit, when changes are made, there ought always to be a definite objective

in view. No useful purpose can be served by changes which are made merely for the sake of change, and there is no more certain path to the ranks of mere manual workers, than to be continually jumping from one place to another in an aimless procession of different jobs.

But in all this it must be remembered that experience is only valuable in exactly the proportion which we make use of it, the knowledge gained may be stored in the mental processes, but it only becomes of service when it is applied, and when it is used as a method of control. Probably you will say, yes, but every one profits by experience, and of course, this is true to a large extent, but how many of us get the full measure of benefit that could be obtained from any given experience ?

The ability to use acquired experience will depend, to some extent, on individual reactions which may very well be expressed as *adaptability*. This, like many other characteristics, will be more marked in some than others, but it certainly may be developed, and when coupled with the ability of critical analysis may well prove to be the elements of greatness if not genius.

To be able to take experience, both one's own and others', to deduce the essential facts, to have the ability to adapt and apply the knowledge thus gained to a different set of circumstances, is probably the most valuable characteristic a graduate, or for that matter anyone else, may possess. Experience is knowledge and knowledge is power, but power is only useful when properly directed and used, just as experience can only be ultimately valued by its effects.

There ought to be conscious efforts to fit in with both existing and changing conditions, and care must be taken to avoid a " one track " mind, not merely as a means of preventing friction, or an attempt to please others, but, as a deliberate action to increase knowledge, to improve the power of observation and to discipline the mind, so that the full benefit of the experience may be obtained.

The object of this is to keep the mind flexible and retain its natural receptiveness. One must avoid the " it was good enough for my father " attitude because that implies a condition of finality and a cessation of learning. Many firms whose names were once well known have disappeared through this, and many men have passed, all too early, into oblivion because of their inability to adapt themselves to changes. Preserve an open mind, feed it with all the information that can be obtained through both the eyes and the ears, and guard it by control of the tongue.

Having thus examined what sort of individual a graduate is likely to be and the effect of circumstances on his development, we are brought to the main question—" What is his place in industry?" This cannot be answered in simple terms of titles or positions, because each of these will vary considerably according to the local

interpretation. A works manager in one part of the country becomes the foreman in another, and titles of that sort serve but little. We must therefore generalise and probably the best term is the one we are all familiar with—" executives " that is, persons holding positions of administration. This is what our graduates will be, this *is* their place in industry, and their ultimate position will be determined by their ability to direct and control the efforts of others. It matters little what branch of industry, finance, or any other form of human activity one may be engaged in, the responsibility for the organisation rests upon those we call executives. At a later stage I shall call your attention to the question of executive ability which, obviously, is necessary in those who hold these positions.

There are 400,000 adult male workers who depend upon the engineering trade of this country for their livelihood, and who must have a technical and supervisory force to control and direct their operations. This force consists of trained technicians who have the necessary knowledge and experience to enable them to produce from the designer's drawing board the commercial products of the trade, and the control of all that goes between the idea and the use of every engineering product, a task of no small magnitude in an industry employing so many workers. If we assume that 1% are directors of various denominations, 1% general managers, 2% departmental managers, superintendents, chief inspectors, chief draughtsmen, planning engineers, technical advisers, and so on, also that a further 10% are draughtsmen, chemists, laboratory workers, designers, ratefixers, experimental and research workers, works and plant engineers, technical sales engineers, assistant managers, and many other positions that readily come to mind, we have a total of at least 15% of the whole.

This, probably very low estimate, means that some 50,000 or 60,000 executives are required to keep the wheels of the trade turning, and beyond question, all who may become graduate members of this Institution should be able to secure one of these positions, particularly as the need for trained men increases with fresh discoveries of the scientist and the development of new processes. Thus, holding in turn one or other of these positions, our graduate will advance step by step until the associate membership stage is reached, and later qualify for full membership. Then, at the height of his success, and the prime of years, he will find himself an old fogey, suitable for retirement on pension (if possible), and most certainly in the way of the young men who are just starting out on life, but he will have had the advantage in that he *has* been a young man.

But more than that, whether he is at the top, or halfway up, or still at the bottom, will depend upon the use he has made of his early experiences. He had the training; he had the ability; but

how did he use them? Every graduate member ought to ask himself—am I heading in the right direction, am I going to get what I want?

Perhaps it would be as well at this stage to inquire just what our graduate wants. No doubt in the beginning most of them will say "I want to *do* something," with all the enthusiasm of young manhood; later they change to "I want to *be* something," and still later "I want to *get* something" all of which are perfectly natural modes of expression, and may be summed up in one word "*success*." But what is success, and how may he obtain it? In the dictionary sense—a favourable issue—the term may be applied to the accomplishment of any specific object, and no doubt every graduate will have his own specific objective, but the matter should be considered in its application to life as a whole, which of course, takes it outside the purely engineering view of the problem.

Like everything else there are degrees of success, or shall I say, points of elevation which some men reach, that place them above their fellows, but while it is not possible for everyone to reach these heights there is no reason to suppose that only those who attain pre-eminence are successful, or that outstanding merit is the only hall mark of success. Rather let us take the view of the average man, under average conditions, and endeavour to ascertain what it would mean to him.

Success, then, would seem to mean a comfortable position, a decent standard of living, the respect of one's fellows, and a good reputation, but none of these depend entirely on what sort of job an individual holds, nor his place in industry. It is, however, the blending of these, together with the judicious use of scientific, technical and practical knowledge that produces the vital distillate of experience, and leads to success.

How then can this success be achieved?

It will be as well to point out that there is still a lot to learn, and for many years technical studies will have to be continued in some form or other. This is absolutely unavoidable, and as evidence may I remind you that the Council of this Institution have only temporarily laid aside the scheme, already in existence, for an examination to be applied to intending associate members. A careful study of the technical journals and the journal of the Institution will be of considerable help, a definite systematic course of training will be necessary where specialised work is undertaken, and if the individual really means to achieve success he must keep abreast with the developments and progress that is being made in his particular branch of the industry.

He must also begin to make a careful study of his fellow men. I have already mentioned this and make no apology for returning to the question, because the sooner he is able to see other people's reactions, the sooner he will learn to master himself, and there can

be no doubt that to know one's own weakness is to know one's own strength. To be able to adequately guide and direct others means something more than merely being placed in that position, it means the possession of that almost indefinable quality known as executive ability. This is *not* the mass mesmerism of the orator, nor an appeal to the ruder instincts of mankind, but a far different quality which gives confidence to the timid, restrains the over forceful, spurs the laggard, and produces results, without ever becoming obtrusive itself. Whether one can acquire this characteristic in a marked degree or whether those who have it inherit it, is a moot point, but it is essential that every executive should have it to some extent, and no doubt much can be done to develop one's abilities in this direction.

It will be obvious that success will not come to the holder of diplomas, possesser of titles, or the man in a responsible position. It will only come to those who have worked hard to fit themselves for the responsibility and are deserving of it.

And so we come to a final summing up of the matter, and for this every graduate will have to be his own judge and jury. The graduate's place in industry will be determined by his ability to use the technical training he received, before his admission to the Institution, to the best advantage, by taking and following up every opportunity to obtain additional information and knowledge of a more advanced nature, by discovering what particular direction he is best fitted for and taking steps to ensure that he is placed in a position where his talents may be properly exercised, by endeavouring to obtain experience which will make his services more useful and valuable, by making a study of his fellow men in order to discover his own weakness, and by cultivating the mental attitude necessary in executives and leaders.

There is, however, one other aspect to which I should like to draw attention, that is, his outlook on life. He must be purposeful, determined and resourceful. He must feel that he has a mission in life and devote himself to it with zeal and enthusiasm, determined to surmount every obstacle which may interfere with his progress, and use every possible resource to achieve that object, but with that there must be a realisation that there are others, with similar hopes and aspirations, who are entitled to claim the same privileges, and who will have exactly the same rights to success. No man can claim to be successful if he has advanced himself by completely ignoring the needs of others. In this he will have to exercise tolerance and sympathy with those who need it, to be patient with those who are headstrong and rebellious, to cultivate a broad-minded outlook on all questions affecting his work, to profit by the experiences of others, to avoid assuming an air of superiority and always be willing to listen to the advice of others, even though he may not adopt it, to

remember that whatever his position he is *part* of an organisation and endeavour to fit in with the remainder, while preserving his own individuality so far as possible. All these at least, are requisites for success and without them the graduate cannot assume his rightful place in industry.

I recommend a careful and minute study of Mr. Groocock's paper on the "Functions of a Production Engineer," and the brochure published by the Institution, "The Making of a Production Engineer." The information contained in these publications will be found invaluable, not only to the graduate in his early stages, but to all who are anxious to increase their own personal knowledge of production technique, and qualify for work of greater responsibility. These papers clearly indicate the training required and the nature of the work involved.

In this paper I have endeavoured to show how these influence the individual, and what steps he should take to obtain the full benefit from his knowledge, and his final place in industry depends entirely on his ability to put into effect the essential facts now laid before him. I realise that I have ventured outside the ethics of the purely engineering aspect of the subject, but it would be impossible to review the question without doing so, and I fear that I have only been able to put into words that which you are all conscious of, and in some form or other, the problem no doubt is as old as history, but if the compilation of these matters into one short paper helps our young men to visualise what steps to take to arrange their thoughts in relation to their daily life, and their future conduct, I believe I shall have achieved something, however small. In conclusion may I quote Shakespeare's well-known lines: "Men at sometime are masters of their fates, the fault, dear Brutus, is not in our stars but in ourselves that we are underlings."

Discussion.

MR. W. G. GROOCOCK: In Mr. Youngash's paper he mentions one point on which we can compliment him to-night as having achieved, and that is, he mentions success and defines it. I venture to say that he has met with a great deal of success in his attempts to define the position of the graduate in industry, It is an extremely difficult subject to tackle, and in the short time at his disposal he has gone over all the essential points, so that anything I may say will be merely to amplify some of the things that he has mentioned.

Mr. Youngash finished with a quotation from Shakespeare, and wishing to be different I will start with a quotation from the same author, viz. :—"There is a divinity which shapes our ends, rough-hew them how we will." If we apply that to the production engineer, and assume that Shakespeare was not laughing when he wrote it, we must conclude that if he was thinking of the production engineer, then he expected us to be just roughers out, but I do not think that is our position in industry to-day. In my opinion the production engineer is definitely a man who can formulate a plan to achieve a given object, and if I am right in that, one cannot accept that particular statement that we are just to rough the job out and to depend on a divinity to finish the job off. If, however, we carry that quotation from Shakespeare to its logical conclusion, by applying it to our graduates we might say that the divinity that Shakespeare had in mind was the Institution of Production Engineers; then we realise that while the Graduate might do a little roughing out, the Institution will, I am quite sure, do its utmost to shape those ends in the desired direction.

We are confident of that to-night, because Mr. Youngash has definitely put down in writing some of the things that will be considered in years to come as very concrete pieces of wisdom for all our Graduates. Personally I do not think that Graduates are just going to be satisfied with the roughing out job that Shakespeare speaks of, but, gentlemen, before we can finish a job we have to make a start on it, and usually in all our processes there is some roughing out to do. If we have to plan a piece of work, what are our first steps? We make some very rough diagrams which nobody but us can understand, and if we are interrupted for a couple of hours we cannot understand them ourselves! That is the normal procedure, but eventually you get something that is not a rough diagram, and we begin to get towards the finished product.

I venture to think that our Graduate between the ages of 21 and 30, will go through that roughing period, but he will finally step

into the position of the artist who can and will plan the finished result.

In his paper Mr. Youngash has emphasised in several places the effect of character. He points out—and rightly—that the period between the ages of 21 and 30 is when character is in the melting pot, and it is then being moulded into its proper relation with the rest of the world. You will remember probably that when I tried to draw up a specification for a successful production engineer, I placed character first, and I would place character first in any specification for any human being, so of necessity it has to go first in the specification for a production engineer. Character is of tremendous importance. In my experience I have known many cases where positions have been open and the choice has been narrowed down to two or three people, and the most likely man has been one who seems to have just those characteristics that would ensure him making a success of the job, but when all the facts have been examined there was, in the mind of the examiner, some little kink in the character of that individual, and quite often one sees him passed over for a man who is of lesser ability in a technical sense, but whose character has been known to be sound.

In building up a production engineer we should do just the same as we do with a piece of mechanism. We start with a piece of material, and we put into that piece of material some roughing out and some finishing, and we finally make a mechanism of it, but if the material is not sound, if the character is poor, we probably get a poor mechanism after we have spent all our time dealing with it. That is why I want to impress on our young men the importance of character.

In a separate part of the paper Mr. Youngash spoke of experience, and he suggested that in those years 21-30, it would be advisable, if at all possible, that a young man should move so as to get the necessary experience, and I agree with that. He should move, not only from one position to another, but from one town to another, where possible. In some large establishments moving from position to position allows a man to get more experience, but it does not give him that wider experience of life which is necessary later on. You cannot really have that unless you have change of environment, and change of environment can usually only be obtained by changing firms. Mr. Youngash pointed out the difficulties and many young men would say—" there are certain difficulties which make it necessary for me to stop right here." All right ; in that case you must definitely get all the experience you can in that one firm by moving as opportunity presents itself, but do not assume that every move you make must of necessity lead to your financial advantage. You may move to a job where the money is no more than it was at your previous job. If you are satisfied that this experience is going to be

useful in your future life, then such a move is worth while. Experience of that description is like a reserve account in the bank which you cannot draw on during those early years.

Now the subject of the paper is "The Graduate's Place in Industry." So far as our industry is concerned, the Graduate's position is definitely in every position that we can find, from finishing apprenticeship as far as he can go. How far you can go in any case will depend, as Mr. Youngash has told you, on the experience you can accumulate, but that experience nust be definitely known to the people you are working for. One of the first things that the graduate should take advantage of is, that whatever experience he has got, he should pass on to someone else as soon as he can, so that people round him know that he has had experience. I have known young men who had a good accurate knowledge of a particular section of their work, and the people who have been running them have gone on for years and years without finding out that they had that experience. There should be some way of bringing this to the notice of your employers, and I would suggest that reading a paper before your own Graduate section is a sure way of getting over to your manager or superintendent the information that you know something about that particular job. It does not mean you should always have the "I am" feeling, or the "I know" feeling, but you do, all of you, have much more knowledge of one section of your business than another, and when you feel that you know something extra of a given subject, then I feel it is wickedly neglectful on your part not to let your higher executives know that you have that knowlege, so that they can take advantage of it. If you are capable of analysing yourself, and you know your weak spots, you could definitely tell the same person where you are weak, and ask them for some chance of getting experience that will strengthen you at that particular point. Do not be backward—that is the advice I am offering to all graduates—do not be backward in bringing to the notice of the people who are running you any special qualification that you may have, or think you have. You will probably find they do not think you have got so much after all, but you won't have done any harm ; they will think sooner or later "We want some-one who knows something about that, and the man is so-and-so" and you will get your chance.

Just think over that and do not keep anything up your sleeve with the idea that you are the only person who knows it. If you know anything at all ; if you are fairly well up in one particular phase of the work which is going on, let your people know it, because if you don't, it is like hiding your head under a bushel—you won't be seen.

I have only a few more words to say. At the beginning I mentioned that Shakespeare's divinity did not intend you to remain as just

roughers out, but expected you to be a finished product, even if he did expect that the young production engineer would help in the finishing of that product, but if you are to be successful, it will depend, as Mr. Youngash has pointed out (in several places) on your own efforts. In one particular direction, however, it will depend more than in all the others, and that is your capacity to analyse yourself, your own weaknesses, and to determine to strengthen those points where you feel you are weak, and to plan a definite course of action. We production engineers pride ourselves on being able to plan a job from beginning to end. I want the graduate to take his own life, plan it during that period of 21-30, plan a line as direct as possible to his objective, and having made his plan, pursue his course as vigorously as possible, keeping his eye firmly fixed on the goal he has planned to reach.

MR. I. H. WRIGHT (Section President), read the following communication from MR. J. A. HANNAY, who was unavoidably prevented from being present :—

"I am convinced there are more opportunities for the young production engineer of to-day than at any other time in the history of engineering. I have remarked before that it is computed the production capacity of the country has increased twenty-three times since the commencement of the twentieth century ; engineers can claim a large share of this advance, and anyone with a little vision must see the possibilities ahead. What an opportunity for graduates !

"I often wonder what the young engineer is thinking of, when about twenty-one years of age—perhaps he has passed the graduate examination and been accepted as a graduate of the Institution. I would like to ask him to pause and look back on the past fifteen or sixteen years, or thereabouts. (1) A period in a preparatory school. (2) A period in a more advanced school. (3) A period in a higher stage—technical school, college or university. Prepare—prepare—prepare. For what ? *His place in industry.*

"I now suggest he looks into the future. Has he a plan ? Not merely a three, four or five years' plan, but something like a ten or fifteen years' plan (remember, he has just about completed a fifteen years' plan) and during that time he must press steadily on, completing the tasks entrusted to him ; many will be irksome, and he must let all see that nothing daunts him—as difficulties arise he must realise they are to be overcome.

"I am convinced that the anxiety displayed by young graduates who want to jump into good jobs the moment they are out of their time is often a handicap. There is so much more to be learnt than any textbooks or instruction can give. The school of experience must be sought, and I know no better help, when going through

that school, than being associated with, and taking part in an Institution such as ours.

"The graduate has to educate himself in the hard school of experience in order to equip himself and be in a position to develop as an associate member, and later as a member, and then not merely *in* industry, but definitely helping industry and finally guiding and controlling industry.

"There is not a possible doubt that, to the graduate of, say, about twenty-one years of age, the next ten years are the most important and will influence his final position in industry. I have said there are more opportunities for the production engineer to-day than at any time in the history of engineering, but they must be men of quality, vision, resource and experience. I do not know of any soft jobs or how to find them, but I *do* know that jobs worth having are hard and get harder, and the only compensation is that one's capacity is increased as jobs are mastered, and so from strength to strength."

MR. W. H. BUTLER: As one who is in years, perhaps, about midway between the speaker to-night and the graduate about whom he has been talking, perhaps I may be allowed to say that I have come to appreciate much more in the last few years the need for this experience about which he has spoken, and about which I as a young man, with other young men, was very impatient at one time.

Mr. Youngash has also spoken about success and emphasises, as did Mr. Groocock, that it depends on character coupled with technical ability or technical equipment. There is one particular aspect of success which I at any rate have come to realise more about in the last two or three years, and that is that it depends on confidence. Our own success, our own happiness, being able to feel right with ourselves (that we should get if we do what we set out to do), depends to an increasing extent, it seems to me, on our ability to build up confidence among those around us, confidence in ourselves, both amongst those below us and those above us in the works and round about us. As Mr. Youngash pointed out, it is much more than merely being technically equipped, however brilliant we may be.

Mr. Groocock has spoken of passing on some particular skill or experience that we have, in some particular line which those around us are not aware that we have.

There is one snag here which I should like to ask about and which others may have come up against as I have myself, and it is the question of personal jealousy sometimes. Perhaps one has had particular experience or knowledge of some particular line outside one's routine activity, and if it is mentioned or brought to the notice of those above it is sometimes apt to inspire jealousy in the department whose sphere that really is, with unpleasant results.

MR. YOUNGASH: There are many side issues which can be

brought into a subject like this, and whilst I did try in the beginning to steer clear of them as far as possible, matters of this sort will crop up, that is where the value of experience comes in. The man who has actually experienced the miseries that can be produced by petty jealousies will learn from experience the best way to deal with them. They do arise, and they are matters which have strictly speaking no bearing on the technical or ordinary business life of an individual except so far as they affect the business, because jealousy, like other human characteristics and emotions, arises from an individual complex. People *are* jealous of one another, that is one of the things we have to expect, but the sooner we acquire the necessary experience to know how to handle situations of that sort, then the more readily we shall be able to get out of them, the easier we shall be able to let the shafts of cynicism and jealousy pass you by and leave you unharmed.

MR. G. A. WOOD : I must congratulate Mr. Youngash on tackling this paper and giving us a very interesting point of view on such a subject which might easily have been handled otherwise. Technical ability is the main thing. That is granted. Everything must be in proportion, but I have a case in mind from my own experience, about this time last year. Two other men, both practical men, said a job could not be done a certain way. I said it could be done. After about three weeks we found out that was the only way that job could be done. Those people had had the same experience in that particular line, but by sticking to a few technical principles I managed to get away with it.

I must say on behalf of the graduates here to-night that we appreciate very much Mr. Youngash's paper, and also Mr. Groocock's remarks, as these gentlemen have for several years taken a definite interest in the graduate section, and whilst I think we do not feel we can raise any controversial points we do very much appreciate the advice given by them.

MR. YOUNGASH : I very much welcome what criticisms that you care to make, in particular in disagreement. I would much rather you should say frankly, " I disagree with something you have said." than that you should go home and feel that your evening has not been worth while. If I have inadvertently conveyed to anyone the idea that I deprecated or even minimised the full advantage of technical training, I herewith offer my humble apologies because I had no intention of doing so. All I wished to do was to point out that technical ability alone would not take you very far.

MR. E. T. COOK : I think we have listened to a paper to-night from which not only graduates but anybody can derive very considerable advantage. Mr. Youngash has dealt with the subject in an extremely logical manner, and has expressed himself so clearly that I can only say that I very much envy him his ability as a

speaker. I will proceed to one or two rather disjointed remarks about the paper. As he says, there is no point in always agreeing with him, so I am going to disagree with him on one point, and that is, he referred to the place of the production engineer in industry, but he referred only to the engineering industry. I think myself that was very definitely wrong. There is a place for the trained production engineer in all industries, in production of any kind; it should not be limited to engineering.

Applications have come before the Birmingham Committee from men who have been in the food and similar industries. I have in mind also my son who has trained as an engineer in this country, but at the moment is applying a production engineer's outlook to a very big farm in Kenya. I consider they are rather extreme cases, but it is very easy to see in the case of the member of a food firm that the production engineer has a very definite place, and I would like Mr. Youngash to express himself on that particular point.

Referring to some remarks of previous speakers, particularly the last one, I think he touches on a point where the young man is rather apt to lose his perspective. Knowledge may be compared to the equipment of a toolmaker. A man may have a very good micrometer and all the various measuring tools that a toolmaker requires and still be an unsuccessful toolmaker. An executive must have the knowledge of how to apply that knowledge, that is going to determine his success. He quoted a case in which had knowledge which other people had not and therefore succeeded where others had failed. I think he lost his perspective. He had also the ability, energy and courage to apply it, and that is what I think Mr. Youngash and other speakers wanted to emphasise.

Personally I rather look for some more simple formula than has been used. I would sum up one of the chief qualities that a production engineer must have in order to succeed in his application of knowledge by saying that he must be a manly man. Everybody seems to be quoting Shakespeare. I think Shakespeare's definition of a man was "His life was gentle and the elements of love so well mixed up in him that nature might stand up and say to all the world, 'This is a man.'"

I rather fancy I quote to prove that Shakespeare, perhaps, was not quite correct on what comprises a man, because most of the successful people in the engineering industry could not be described by saying that their lives are gentle and the elements of love are well mixed up in them! I feel that, gentle as Mr. Youngash has shown himself to be to-night, the real reason why he is in a position to give us this lecture is because he has found many occasions on which he has had to show other qualities of manliness than those Shakespeare refers to.

I think there is another light we can put on the question of the

brought into a subject like this, and whilst I did try in the beginning to steer clear of them as far as possible, matters of this sort will crop up, that is where the value of experience comes in. The man who has actually experienced the miseries that can be produced by petty jealousies will learn from experience the best way to deal with them. They do arise, and they are matters which have strictly speaking no bearing on the technical or ordinary business life of an individual except so far as they affect the business, because jealousy, like other human characteristics and emotions, arises from an individual complex. People *are* jealous of one another, that is one of the things we have to expect, but the sooner we acquire the necessary experience to know how to handle situations of that sort, then the more readily we shall be able to get out of them, the easier we shall be able to let the shafts of cynicism and jealousy pass you by and leave you unharmed.

MR. G. A. WOOD : I must congratulate Mr. Youngash on tackling this paper and giving us a very interesting point of view on such a subject which might easily have been handled otherwise. Technical ability is the main thing. That is granted. Everything must be in proportion, but I have a case in mind from my own experience, about this time last year. Two other men, both practical men, said a job could not be done a certain way. I said it could be done. After about three weeks we found out that was the only way that job could be done. Those people had had the same experience in that particular line, but by sticking to a few technical principles I managed to get away with it.

I must say on behalf of the graduates here to-night that we appreciate very much Mr. Youngash's paper, and also Mr. Groocock's remarks, as these gentlemen have for several years taken a definite interest in the graduate section, and whilst I think we do not feel we can raise any controversial points we do very much appreciate the advice given by them.

MR. YOUNGASH : I very much welcome what criticisms that you care to make, in particular in disagreement. I would much rather you should say frankly, " I disagree with something you have said." than that you should go home and feel that your evening has not been worth while. If I have inadvertently conveyed to anyone the idea that I deprecated or even minimised the full advantage of technical training, I herewith offer my humble apologies because I had no intention of doing so. All I wished to do was to point out that technical ability alone would not take you very far.

MR. E. T. COOK : I think we have listened to a paper to-night from which not only graduates but anybody can derive very considerable advantage. Mr. Youngash has dealt with the subject in an extremely logical manner, and has expressed himself so clearly that I can only say that I very much envy him his ability as a

speaker. I will proceed to one or two rather disjointed remarks about the paper. As he says, there is no point in always agreeing with him, so I am going to disagree with him on one point, and that is, he referred to the place of the production engineer in industry, but he referred only to the engineering industry. I think myself that was very definitely wrong. There is a place for the trained production engineer in all industries, in production of any kind; it should not be limited to engineering.

Applications have come before the Birmingham Committee from men who have been in the food and similar industries. I have in mind also my son who has trained as an engineer in this country, but at the moment is applying a production engineer's outlook to a very big farm in Kenya. I consider they are rather extreme cases, but it is very easy to see in the case of the member of a food firm that the production engineer has a very definite place, and I would like Mr. Youngash to express himself on that particular point.

Referring to some remarks of previous speakers, particularly the last one, I think he touches on a point where the young man is rather apt to lose his perspective. Knowledge may be compared to the equipment of a toolmaker. A man may have a very good micrometer and all the various measuring tools that a toolmaker requires and still be an unsuccessful toolmaker. An executive must have the knowledge of how to apply that knowledge, that is going to determine his success. He quoted a case in which had knowledge which other people had not and therefore succeeded where others had failed. I think he lost his perspective. He had also the ability, energy and courage to apply it, and that is what I think Mr. Youngash and other speakers wanted to emphasise.

Personally I rather look for some more simple formula than has been used. I would sum up one of the chief qualities that a production engineer must have in order to succeed in his application of knowledge by saying that he must be a manly man. Everybody seems to be quoting Shakespeare. I think Shakespeare's definition of a man was "His life was gentle and the elements of love so well mixed up in him that nature might stand up and say to all the world, 'This is a man.'"

I rather fancy I quote to prove that Shakespeare, perhaps, was not quite correct on what comprises a man, because most of the successful people in the engineering industry could not be described by saying that their lives are gentle and the elements of love are well mixed up in them! I feel that, gentle as Mr. Youngash has shown himself to be to-night, the real reason why he is in a position to give us this lecture is because he has found many occasions on which he has had to show other qualities of manliness than those Shakespeare refers to.

I think there is another light we can put on the question of the

changing of jobs. I like the idea of the old journeyman who went from job to job. It was in the journeyman stage that he obtained his experience. When you have got to an executive position I think it is very unwise of any man to consider too easily the question of changing. I agree with Mr. Groocock that if he does change he should not change merely from the point of view of increased £. s. d. but rather get a little more capital in his bank. I think probably the period immediately after apprenticeship is the most important time to change, but before he has got his feet on the first rung of the executive ladder.

MR. YOUNGASH: I was very pleased to hear Mr. Cook start out by saying he was going to disagree, but unfortunately he quickly had a relapse and came back to saying that he agreed in another way, because you will have noticed that in the example he quoted he said that in one instance he referred to a man who was an engineer on a farm and in the next example a man who was an engineeer in a food factory. Well, really Mr. Groocock ought to reply to this. He is our exponent of this particular aspect of membership. Mr. Cook used the word engineer and therefore I think I may reasonably claim that my implications or advice would be equally as applicable to men who were production engineers at a food factory. Anyway I am not going to cross swords with Mr. Cook about that, because to me an engineer is an engineer, whether he is on board a ship or whether he makes motor cars, he is still an engineer. There may be differing grades of engineering, different aspects of the problem, but the principles remain the same.

With regard to the other part the position is not quite so clear perhaps as Mr. Cook seems to think. I take it that in the main our graduate will have had the bulk of the operating experience that he is going to get at the time he joins the Institution. The old journeyman stage has disappeared. Boys are no longer taken on as trade apprentices to any extent. The Employers' Federation have been instrumental in producing a certificate which will show at the end of the period that a boy or young man has received training and has had experience in operating machinery and in processes in the shops, and that this is the only remaining relic of the old apprenticeship system. To-day our young men are getting that experience either in the shops or in the technical schools or in both, and at the same time they are qualifying for what is usually termed a better job. At the end of the period when that training ceases, at the age of 21, 22 or 23, that is the time when they attempt the graduate examination, and having reached that stage of development they are then looking forward to becoming not merely operators, not pushers of files and what not, but executives, and I think that is just where the difference comes in. When I talked about getting experience I had not in mind the experience which a man gets who

goes from a lathe at Bill Smith's to a lathe at John Brown's, but rather in the broader sense of the word, of getting additional experience as an executive.

This Institution does not admit as members those who are surely machine operators or fitters or something of that sort, and of course you will realise that my remarks were intended to be addressed to men of the executive type and those who are starting out on careers as executives rather than purely operators. It may be argued, and quite reasonably, that a man can have additional experience as an operator which is of benefit to him ; we are not going to dispute it, but it was not that particular class that we had in mind when we planned this address to-night.

MR. C. K. HUGHES : I should like to pursue the question of the the value of techincal knowledge. I have thought quite a lot about it in the past. It seems to me that as a man progresses through an organisation the value of his technical knowledge increases up to a point, a peak, and then decreases. It seems to me that probably the point at which his knowledge is at its maximum value is where a man reaches proficiency as a planner or tool designer, and I should like Mr. Youngash's opinion on this. I think that as soon as a man becomes chief of either of these two departments the value of his technical knowlege immediately begins to decrease. He then becomes 50% planner and 50% organiser. It would seem as if, after a certain point, we should not pursue too much the technical side of the question but rather try to increase our general experience and education in other directions.

MR. F. A. HAWKINS : The lecturer has mentioned the training of graduates in technical colleges ; as one engaged in that work I should like to say a few words. I do not propose entering this controversy about how much technical knowledge students should have. I did rather think myself that the lecturer belittled it somewhat, but he has explained himself since and we have accepted it.

With regard to some of the boys we are getting at the present time. I am not very hopeful ; the type that is coming along at the present moment is not of a very high standard, but here and there one finds budding production engineers ; I personally think that those who do receive a high standard of technical training will be the men who will be the production engineers of the future.

I would like to point out in the paper there was no mention of the love of one's job. I believe that success comes to the man who loves his work, to him who makes his work his recreation, and the man who has no love for his work is a square peg in a round hole.

The young engineer would, I think, be rather dismayed to hear Mr. Youngash's remarks about the hard knocks he is going to receive. I can only say that at the end of it he had better assume that it is better to have " loved and lost than never to have loved at all."

Regarding this roughing out business, I am one who has been bumped about to no little extent and had all that roughing out process. I am almost in the class of the man who is getting beyond the prime, but the young man of to-day has a better outlook than we had. The way things are at present a young fellow should be full of beans for the future.

MR. YOUNGASH : I do not know how I could have impressed on any person that I was trying to belittle technical knowledge. I said in the very beginning that the Institution was taking great care to see that a young man was up to a very high standard, and that our technical school training has changed to such an extent that they were able to take the course for production engineering which I take it you are perfectly familiar with, and that this enabled them to sit for the entrance examination of the Institution. At a later stage I stated that technical training would still have to be continued for a period of a number of years so that they could keep abreast of their jobs and get some knowledge of what was happening up to the moment in the departments in the way of new processes and advancements of science. I did not say anything about love : I rather contented myself with quoting a few lines of Shakespeare, but I did say that the young production engineer would have to be determined, resourceful (I think those were the words I used) and feel he had a mission in life, which of course, is exactly what you are saying perhaps merely in differing words.

I agree very cordially with that aspect which you put as love for one's job. I have previously said on this platform that the successful man is the man who can work ten hours a day at his job and then come back and work two hours overtime for love of doing it. One must have that regard for one's job, one must have an appreciation of the fact that it is the job you have voluntarily undertaken to follow and once you put your heart and soul in it you cannot help but make your mark.

MR. H. G. AYLING : I was rather surprised to hear Mr. Youngash say that the day of the journeyman was over, although I agree that an operator in the present-day job does not need so much practical training or tuition. At the same time I consider it is still very essential for the works executive. During latter years so many apprentices seem to spend a large part of their time in offices of one sort and another during their apprenticeship at the expense of practical work, that it seems to me a point which they would do well to consider. After they finish their apprenticeship, I think a few years as an improver is still as necessary to-day as it was several years ago. I should like to know Mr. Youngash's opinion on that matter.

MR. YOUNGASH : I think that conditions have changed, and a man to-day is either an operator or else he is an executive. Years

ago a mechanic was a man who took a piece of steel, he perhaps had a sketch or a sample given to him, he forged it if it required it, shaped or planed it, drilled it, filed it, fitted it into place and hardened it, and then rubbed his hands on a piece of dirty rag and went home, having done a day's work. All that is changed, and it has changed for a very simple reason. Men in the position of Mr. Ayling have split up the jobs to such an extent that we now give each of them a little bit, with the result we have people going round wailing and deploring the fact that the skilled man has gone, when actually the facts are that the bulk of our men are much more highly skilled than ever they were, and subdivisions of the work into small parts has brought that condition about. Instead of taking a piece of raw material and carrying it to the logical conclusion a man now does a little bit but he does it very well, he does it in half the time.

There is a much more sharply defined line between executives and pure operators than ever there was before. You must remember I am not speaking to operators, I am talking to executives. We started out with the young man who became a member of the Institution and was holding a position as a minor executive, so that the question of whether a period of serving as an improver has advantages or not is really outside the scope of this paper.

If a young fellow feels he would like to spend another five years in running machines, I should be the last to object. What I should say to him is, "Ask yourself if at the end of five years you will be more likely to get out of it than you are now. If you are, do it. If you are not, get out of it."

MR. WRIGHT: Mr. Youngash made the very wise statement in the early part of his paper that until a young man reached the age of graduateship he was hardly in a condition to select his line. A lot of youths are put into occupations by their parents, who have some fancy for it, when the youths themselves are really not at all suited. If they are adaptable they may just get through, but the youth who really gets into the line he is built for and towards which his temperament and tastes incline, will make much more rapid progress, and I say that at the age of twenty-one, not sixteen, the student might be expected to have some judgment, he has at any rate some knowledge of engineering training, and it is easy for him to decide whether he will go into the design side or executive side, which is a very serious step. I confirm what Mr. Youngash said, that the student whose temperament runs in the direction of executive work is well advised to take the step at that time and not to begin at sixteen, assuming that up to the age of twenty-one he has had a general training round the shop.

There has been a very great deal said about experience to-night, but I think it has just been left open for me to define in some way what experience really is.

Experience is not something we live through. We may pass through a lot of experience, but whether we benefit by it is another matter altogether. In my opinion, experience consists of doing the job that you have to do now with a full sense of responsibility, and making every effort to make it a success, and when it is done, weighing it up and finding where you might have done rather differently, and resolving next time anything of that kind occurs you will do it differently. That is experience.

The average engineer of twenty-one may only have simple duties to do in the executive department of his works, they may be rather routine and rather tedious, but if he is enthusiastic, having made the selection at twenty-one, he will apply himself to those duties and his superiors will see that he is reliable, that he is interested in his work and is responsible, and is willing to make every possible effort that his work shall be successful. That is the way to get better jobs, promotion is a detail.

Mr. Youngash has spoken about a young man having two or three moves in between the ages of twenty-one and thirty, trying different fields of labour where things are carried out differently. It does not necessarily follow that he will benefit, if when he is in any one of these jobs he just goes on, does not take a responsible interest, and weigh up the effect of his work. He must be gradually making progress, preparing himself for the next job, though he may not get any nominal promotion in the particular job he is in.

One gentleman spoke about confidence. In my opinion confidence does not mean what we call self confidence, going about saying you can do this or that job. Confidence means certainty that if you had this or that job to do you would apply yourself very freely to making a success of it. That kind of confidence is at the back of this experience which I tried to define. I think that proceeding in that way would remove the disagreeable necessity of going up to your superior and telling him that you know quite a lot about so-and-so, will he transfer you to doing that job. I think if you show your ability in the work you are doing it will get round to them. You do not want to say you know about it, will they let you do it, but ask for an opportunity to do it. If your confidence is such a success as it should be and you are successful then you have gained more than that particular point.

Technical knowledge has been mentioned by Mr. Hughes. Mr. Youngash called it technical training very largely in his paper. It is often called technical instruction. It is technical study that is good. The student has got to study himself. It is not what the teacher pours over him, like basting a roasting goose, that matters but what the student observes and works out in a lot of examples, that he does all the homework the teacher gives him and really

assimilates the information, that is technical study and that does count.

Mr. Hughes suggested that when a man reaches a certain responsibility his technical study ceases to be of any importance. In my opinion that is just the time when technical study is important. Up to that time, in the earlier years, when a problem is put before him to solve in the way of his work, he consciously applies his technical studies to it, he is working out something he has learned in the course of his study. By the time he reaches the stage Mr. Hughes mentioned all that study has been absorbed into his judgment, and he has been doing that for ten or fifteen years. Now he supervises the work of other people who are insufficiently trained, he says whether they are doing a job in the right or wrong way. As Mr. Youngash says, he is continually learning. We are all continually trying to keep in step with progress, to keep informed of developments in our own field.

The effect of education is quality of judgment. The effect of technical education is quality of technical judgment. That is my view.

We have had a most interesting evening, and a very fine discussion. I hope that all those who have taken part feel they really have helped this subject forward.

I have the greatest pleasure in proposing that our best thanks be given to Mr. Youngash and those gentlemen who have taken part in the discussion for their contribution to our evening's work.

MR. G. WILLIAMS (Member): I have been associated with Mr. Youngash for some number of years in various capacities, and it has been one of my pleasures or privileges to criticise from time to time remarks that he has made. I came along here to-night hoping to join issue with him on some of the statements that he might make, but he has left me nothing to say. I feel that nothing Mr. Youngash has said, so far as I am concerned, admits of any criticism. Mr. Youngash said in his opening sentences he rather regretted having undertaken it. I am sure, having heard it, it would have been regretted far more if Mr. Youngash had not undertaken that work. It has been a most interesting subject. At the moment I am just wondering myself as to what to do with a son who is just about leaving school, and I have now got sufficient knowledge to know what to do with him. He will be a production engineer, and I shall, as soon as we get the paper in print, present him with a copy, and in a few years time, of course, he will reach the height to which all the best young men wish to ascend. I have very great pleasure in seconding the vote of thanks.

The vote of thanks was adopted with enthusiasm.

MAINTENANCE OF MACHINE TOOLS.

Paper presented to the Institution, Glasgow and Edinburgh Sections, by J. W. Mallett, M.I.P.E.

TONIGHT we are going to discuss the Maintenance of Machine Tools. I say discuss advisedly, because, although I was asked to read a paper on this subject, I am no expert and have therefore tried to gather together some facts and thoughts—some which exist and others which do not—so that there will be subject for discussion. What I have to say is much on the same lines as was presented at an informal meeting in 1934 and those who were present will, I trust, forgive me if I repeat myself.

First of all, what is " Maintenance " ? What does the dictionary say ? Maintenance is the act of maintaining, sustenance, support, continuance, defence. Further, to maintain is to hold, preserve, or keep in state, to keep up, to continue. I like some of those definitions—To preserve, to keep in state, continuance. You will notice they are all active functions and effects.

Now, maintenance and repair are just such important and active functions of the productive side of a works' organisation. Their aim is to maintain the productive efficiency of the equipment, *its continuance*. They are best done actively, by anticipation, to prevent the delays which are inseparable when breakdown occurs. Some emergency repairs *are unavoidable*, but many of these can be used as object lessons for fresh measures of a preventative nature.

Suppose we regard the machine as the engineering body, apart from its exercises, thoughts and designs. Then the Maintenance Dept. is made up of Chinese doctors, surgeons, and nurses. I say " Chinese Doctors " because, in China you pay a doctor to keep you well, and his pay stops while you are ill, until you are well again ; I don't know whether they adopt the same methods with plant engineers. The principle—to aim at well being, to keep in good state is the right ideal. Let us consider the people to do this work, and how it is done.

The head of the Maintenance Dept. should be responsible to the Works Manager, with authority in accordance with the charge for which he is responsible, virtually the well being of the engineering body. The personnel, foremen and men, should be chosen or trained with regard to the work to be done, which demands the following qualifications :—Vigilant observation, reliability, accurate work-

Edinburgh, November 17 ; Glasgow, November 18, 1937.

manship, good judgment, analysis of mechanism, experience, good physique, for this is an asset required in most of the squad, persistence, real downright persistence.

Now we come to organisation. Organisation of machine maintenance may well be sub-divided into the following :—

(1) *Inspection.*

(2) *Preparation* of repair material and parts, including the stocking of a certain amount of purchased spares. Planning of work in advance to be done as opportunity may be made.

(3) *Advisory*, that is, warnings to foremen and men on bad procedure, or lack of good procedure, either of which is detrimental to the well being of the machines.

(4) *Overhaul* of complete machines.

(5) *Emergency repairs.*

In a small plant, the first and last, inspection and repair, may have to be done by the same men. The squad may well be divided into individuals, or groups, responsible for sections of machines. Each man may have a calendar schedule of inspection which will take up part of the day and require certain machines to be examined specifically. In passing, it should be noted that, as a result of intelligent repair and overhaul, these schedules will be augmented and the general scheme gradually improved. The remainder of the day he gives attention to emergence repairs.

For example, to-morrow we will take as a typical day ; he sees that the day has come for the periodic taking up of the bearings on a certain gear-cutting machine. There are specified adjustments to make to the diamond truing slides of a certain grinding machine. There is the hydraulically-operated grinding machine which is scheduled for a change of oil for that day and arrangements to be made to do it in the dinner hour. There is the regular examination and adjustment of grinding wheel spindles.

Then, in the other category come his emergency repairs. There are clutches to tighten, worn or broken screws to replace, welding of a lever broken by careless handling and arrangements for a new one in steel to follow, and so on. The worn screws come really in the second category, but observation should have noted these and, if of a special size, length or shape, they will have been made in advance and only require immediate replacement with no delay in production.

Apart from the Section Schedules, there will be the foreman's diary for periodic examination of mainshafts, countershafts, prime movers, etc., which are so closely associated as to be grouped with machine tools in most works.

Also there are items which may be on test or alterations and improvements which have been made and are to be checked after an interval

of time, to write up either as satisfactory or add to the Section Schedules as experience decides.

How shall we go about all this ? So much depends on the size of the plant and the different types of machines in use. In a small works, the foreman's memory is often a grand schedule. It does break down, though, at times, and the more he can reduce it to planned procedure, the better. He must have time to do it. In larger plants it is undoubtedly easier.

Suppose we take a loose sheet of paper for each machine in the factory and put down the important items which wear, which need adjustment, which are known to be weak, which must be accurate to a known degree to produce the parts correctly, and add a time period to examine or do these things. Get each man to write it up, then the foreman mechanic, then let the operating foreman have his say, then check it against the maker's handbook in case you've forgotten something. Then sub-edit it, and phrase it for lucidity of instruction.

Now we can have the sheets typed in triplicate. We should keep one in a master record file and keep another one for shop use, to be added to as the occasion arises and augment the master record at convenient intervals. Take the third set and sectionise them as meets the size of plant, geography of departments and men available. Then take the sheets for each section and reduce them to a calendar programme. So much for the first day of the month, so much for the second, and so on. Certain items may, of course, only appear every second or third month. If you do this, you will have got a good basis to work on. The doctor will know his patient, and have his visiting lists. I wish mine were as good.

There is another responsibility of maintenance on which something should be said. The addition to and care of safety guards and appliances are important parts of the maintenance scheme. The new Factory Act should give us better guards on our new machines, because at last the maker will be compelled to provide them. Our older ones must also be made safe. To do this properly will, in a factory with, say, six hundred machines, provide continuous work for a mechanic and one or two tinsmiths for many months. How far it should be the province of the Maintenance Dept. to see them properly used, and how far the operating foreman is responsible are moot points and might provide for discussion. The fact remains that the shop foremen, particularly the older ones, look on our measures with some contempt, and the men also are often unhelpful.

Our local branch of the Institution had an informal talk, on one occasion with the Factory Inspector and I am firmly of the opinion

that such a talk, with slides to illustrate it, at a suitable gathering of all foremen and men, would induce a mutual respect and lead to a better sense of responsibility.

The machine tool manufacturers could help considerably. Take milling machines. On a horizontal machine they could give us two lines of bosses at the top of the main frame with projecting rods on which to hang milling cutter guards, large guards which could be easily swung clear or adjusted. I will show you a slide later. On vertical machines similar bosses and vertical rods would provide means of attachment for guards and these in both cases, being designed with the machine, would help to preserve a good appearance.

Improvements.

To return to general maintenance, if this is carried out thoughtfully, improvements can often be made when sufficient scope is allowed. It does not always do to replace the part with one of the same material. Collaboration with the metallurgical department will suggest a better steel, or a hard steel with a tougher core, and in many factories the better material may be to hand. A retrospect on a certain machine, or analysis of maintenance on similar machines, will afford a guide in the purchase of new machines.

To return to our simile of the engineering body, we are more fortunate than the doctor who attends to us, because our machines can be overhauled—taken to pieces, diagnosed, repaired and reconstructed with new parts. In many cases the best way to repair a machine is to stop using it and overhaul it in whole, or part, and often in the process improve its known weaknesses.

The best type of machine maintenance man is needed for this branch with the ability to work to fine limits and carry out minor improvements. Such work is not to be undertaken lightly. Knowledge of the machine functions, the required accuracy and the methods of checking are necessary. The first is a matter of experience, aptitude and liking for the work, with suitable training.

Coming to the details of accuracy and methods I can best illustrate these with a few slides.

A machine's functions are bound up in certain rectilinear parallel and circular movements of the working parts generally throughout the whole travel of the moving parts. Each movement can be measured and checked, preferably in due sequence. Charts of inspection tests are therefore required, but until some few years ago these were not generally available. Lately they are often obtainable from the machine tool maker and a valuable guide, which covers most machines, is Dr. Schlesinger's book entitled "Inspection Tests on Machine Tools."

I do not propose to discuss, or show, his actual standard figures—I have the book with me if anyone is not familiar with it—except

to say that each one must decide where to relax, or tighten up, according to the measure of his product. On boring machines, gear-cutting machine spindles, etc., I have found it necessary to work a good deal finer. As a guide, it was invaluable to me and, after having had to make up for some time our own charts for some of the earlier machines that we overhauled, I managed to get the original book in German, and later the English edition.

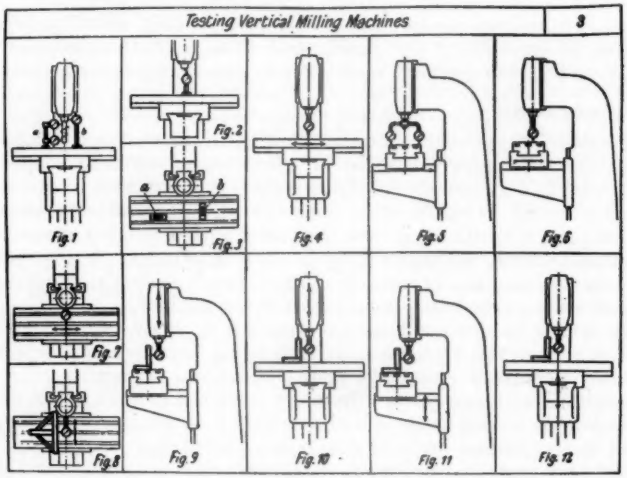

Fig. 1.

Fig. 1 shows some of the tests for a vertical milling machine. Test No. 1 is on the truth of the internal taper of the cutter spindle, by means of a clock gauge against an arbor placed in the spindle, free from dirt and true in itself, after the taper hole has been checked for taper, ovality and finish. Also the external taper or spigot diameter is to be checked. No. (2) is a check for axial slip, or truth of end surface, plus correct thrust-bearing surfaces. On machines where a fine finish is required, one should amplify this check by attaching an accurate large diameter faceplate and applying a reversible pressure.

3—Tests for table flatness in longitudinal and transverse directions, using an accurate level.

4—Rise and fall of the table surface.

5—Work table square with cutter spindle, a necessary corollary of test No. 4. In most cases, the table is allowed to be slightly high at the front, to allow for take-up and spring under-cut—say, one-thou. in 12 in.

6—Surface of table parallel with its transverse movement to and from the column.

7—Centre tee slot, parallel with longitudinal table movement.

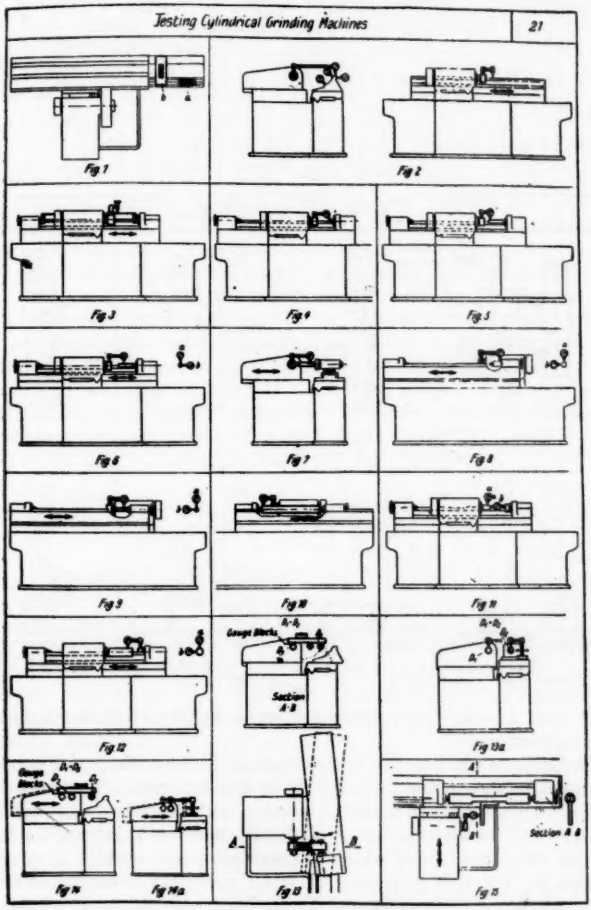

Fig. 2.

For this test, I prefer to use, in conjunction with the clock gauge, an "L" shaped block, which lies inside and hard against the tee slot, and averages the surface.

8—Centre tee slot square with transverse table movement. You will notice here a special tee-square arrangement to suit the tee slot. For the average shop overhauling machines, this can be checked with a square, applied to the table edge, which has previously been made parallel to the tee slot, or a square used with a parallel slip in the tee slot. This is mentioned particularly, as special devices are apt to multiply and become expensive, and simple methods which take a little more time or skill can often be devised.

9 and 10—Vertical movement of cutter slide square to work table in both planes. Note the conventional square is shown here, but we prefer a more solid type, which I propose to show you later.

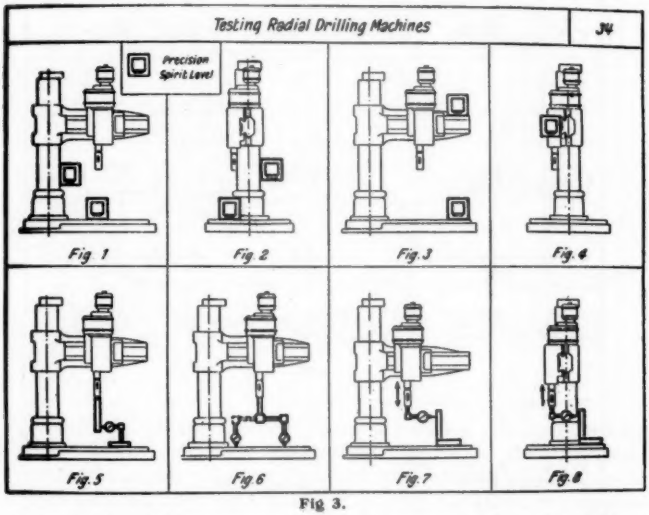

Fig 3.

11 and 12—Column ways for knee square with work table in both directions.

These tests are not the only ones, as in some cases the process is reversed in the actual building up of the machine. For instance, if we look at No. 11, the machine column and its ways, after replaning, if necessary, or re-scraping at any rate, will need a check for fundamental alignment, and whilst the machine-tool-builder may have a special rig for this purpose, we shall probably take the knee and bolt a clock with long arm on to it and traverse the ways on the head of the column for parallelism of ways on face and fitting sides.

For heavy machines, such tests need to be made with the machine column in its working position, not lying on its back, to allow for sag due to weight.

In Fig. 2 we have part of the test sheet for cylindrical grinding machines ; the whole sheet would not go on to one slide. As these tests are straight-forward and well-known, I will not deal with them in detail.

In the second half Fig. 3, there are illustrated, in Nos. 13 and 14, more important tests. Whilst the earlier tests will satisfy the requirements of a machine used for ginding parallel parts only, whenever tapers have to be ground, then the centres of wheel and work must be on the same plane in all positions of work table and wheel slide within an amount of .008 in. for general work.

The method of checking by means of equal diameter discs on wheel and work axes, using clock gauge for flat tables, and level for vee tables, is clearly shown. This applies equally to internal grinding machines. This test is chosen for illustration, because, simple as it may seem, I have on several occasions found even tool-room grinders baffled when taper holes were coming out curved instead of straight, when the wheel was not at the true centre.

But, you may say, I have put the cart before the horse and so far have not discussed the dismantling, the work to be done and the re-building. Well, I wanted to get a picture of what we are to aim at first, and will now deal briefly with the decision and process.

First of all, we must get sanction to overhaul the machine and to examine the merits of such a procedure a sanction sheet should be made up with at least the following information.

MACHINE NO.....
DATE .....
JOB NO.....

MACHINE OVERHAUL SANCTION FORM

DESCRIPTION OF MACHINE .....
DATE PURCHASED ..... PRICE .....
PRESENT BOOK VALUE ..... PRESENT MARKET VALUE .....
COST OF A NEW UP-TO-DATE MACHINE OF SAME TYPE .....
A BRIEF STATEMENT TO DENOTE THE RELATIVE PRODUCTION VALUE OF A NEW MACHINE OF SAME TYPE .....
HOURS IN USE .....
REPAIRS FOR LAST TWO YEARS COST .....
REPAIRS FOR CURRENT YEAR COST .....
LAST OVERHAUL COST ..... DATE .....
SPECIAL REASON FOR OVERHAUL .....
EXTENT OF OVERHAUL PROPOSED .....
ESTIMATED COST .....
REMARKS .....
LENGTH OF TIME MACHINE CAN BE RELEASED FOR OVERHAUL
.....(OBTAINED FROM PROGRESS DEPT).....
OVERHAUL SANCTIONED .....

Assuming that all is in order, then parts need to be cleaned free of dirt and grease. Where a trichlorethylene tank is in use in the factory, it will be made use of, and where this is not a regular facility, one should be considered for the special use of this department. A small one for the small parts and, if it is justified, a larger sized tank for medium size parts. The cost of using trichlorethylene on such parts will be about 4s. 6d. per gallon, per ton of material, plus cost for heating, which will vary in different factories, and it should be noted that where exhaust steam is available, the cost will be almost negligible, as this liquid evaporates at the low temperature of 87°C.

All parts should be scraped, swabbed, or hosed first, or the costs will be doubled, due to unnecessary absorption of clorethylene. The larger castings, such as beds and columns, will need to be cleaned with paraffin and washing solutions. The work of planing, filing, scraping, regrinding, bushing and replacing then proceeds, depending somewhat on the available equipment for this work.

Overhead lifting tackle should be provided, as it is no joke manhandling heavy saddles and slides during the bedding down operations. The processes are known to all here and need no special mention, except perhaps the following: Lapping of spindles and bushes is well worth while. For instance, on a boring machine, it pays to grind the spindle and re-bore the quill to take hard cast-iron liners. These are left for lapping, and the result is well worth the extra trouble.

In this case, as a matter of interest, a problem arose where one or two spindles scored slightly. The wise ones wagged their heads and blamed the lapping compound, but eventually it was traced to the habit of operators, who ejected their boring bars by putting in the drift and withdrawing the spindle smartly, so that the drift hit the end of the quill and ejected the bar. This bruised the mouth of the hole and caused the scoring. A few kind words on the energy required to lift a hammer followed and, in case he did it when we weren't there, we radiused the mouth of the hole with subsequent satisfaction. I mention this, because, if you use a new or refined process, it isn't well to be put off it too easily.

Scraping is another point and can become a fetish. Most men can soon use a flat scraper, a half-round and triangular scraper. A few are adept with the draw scraper and old engine fitters with the two-handled scraper. The Wimet-tipped scraper is useful on steel and for roughing down cast iron. Once a surface is well and closely bedded, it is good enough without feathering. After scraping, and to remove the slight edges, a rub together with a superfine lapping compound is worth while.

I would now like to pass on to equipment. Apart from the usual precision tools, micrometers, verniers, height gauges, sine bar, etc.,

Fig. 4

Fig. 5

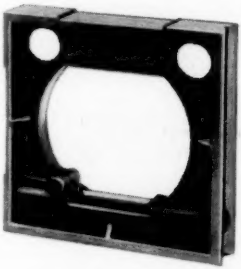

Fig. 6

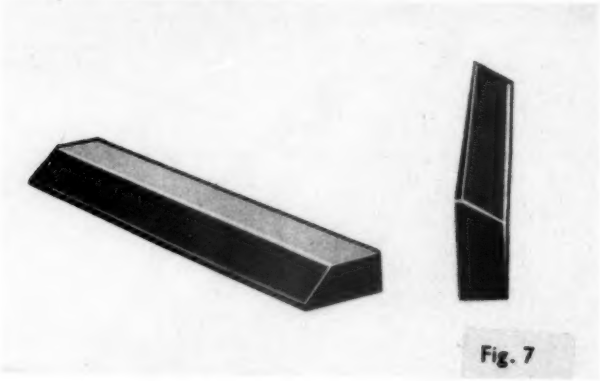

Fig. 7

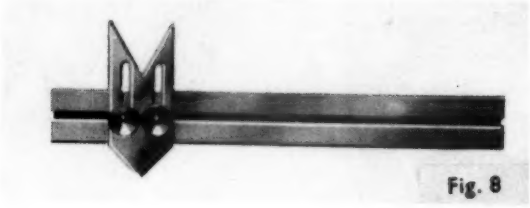

Fig. 8

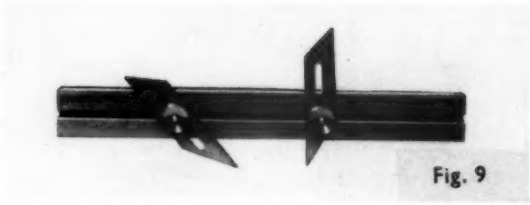

Fig. 9

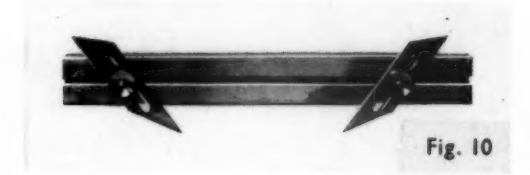

Fig. 10

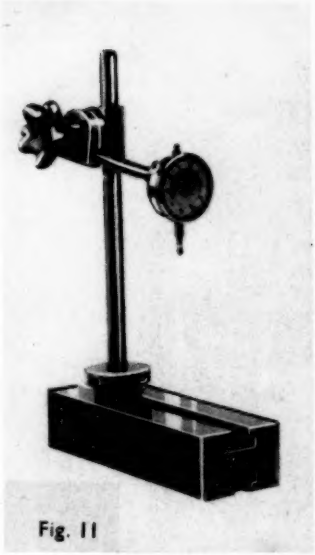

Fig. 11

Fig. 12

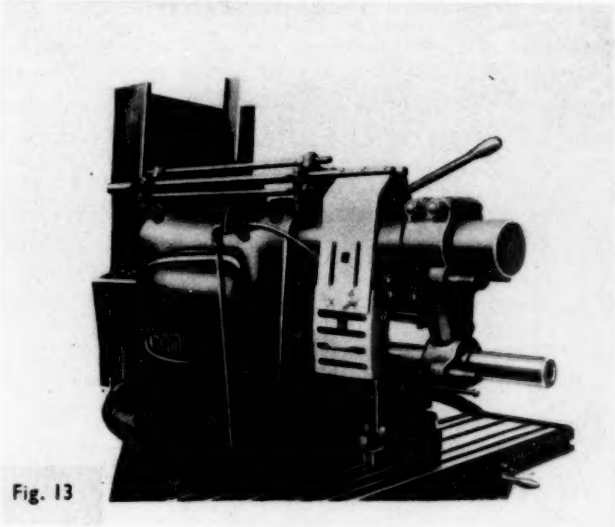

Fig. 13

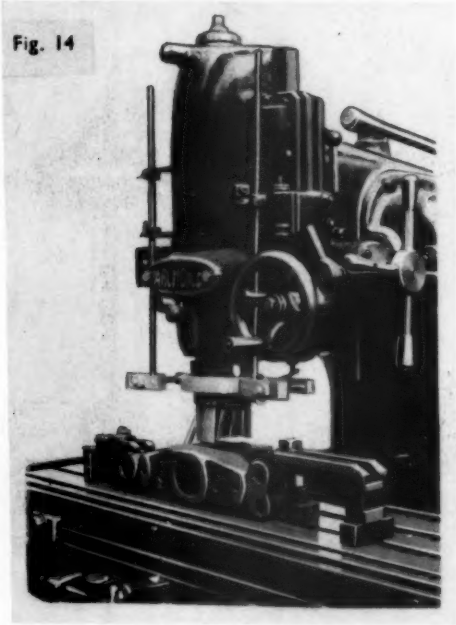

Fig. 14

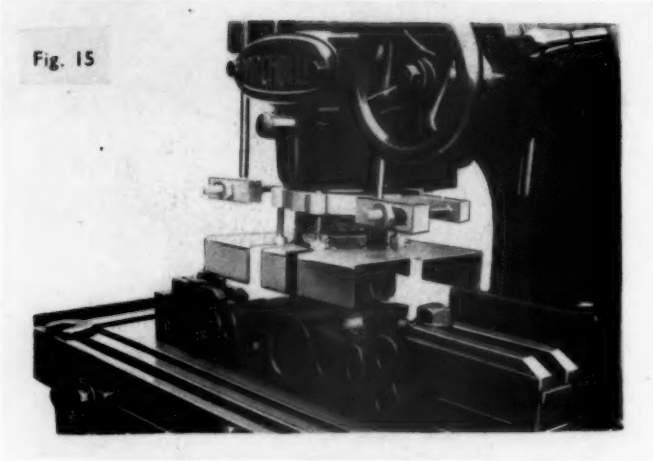

Fig. 15

we shall need, for even a small squad, the following: One large accurate surface table; several small surface tables; and three accurate straight-edge plates.

In Fig. 4, Plate 1 you will notice one of these straight edges is the usual commercial article. The other was made cheaply from an old discarded bed section and, being well seasoned and heavy, is used as a master, the lighter ones of the commercial type being used on the machines.

Fig. 5, Plate 1, shows a master cylindrical square made of hardened steel, ground truly parallel and square on the raised rim faces at each end. This serves for checking other squares and is sometimes used on the machines. The other is a master box section square, or several of different sizes would be useful. This is made of cast iron, both square and parallel on the upstanding leg. A commercial square is a delusion unless very accurately applied. Unless it is itself applied square to the job, the blade may lean either way and give a false reading. Again, where a clock gauge is to be traversed up and down a square, the block or cylindrical square is easier to use and reliable.

Fig. 6, Plate 1, shows a precision square spirit level, to read as accurately as $1\frac{3}{4}$ tenths of a thou. per $^{3}/_{32}$ in. graduation on the bubble glass, that is on an 8-in. base. For an idea of its many uses, I will show another Schlesinger chart.

Fig. 7, Plate 2, shows Vee edge strips or blocks for bedding and measuring. The number of these will depend on the differing sizes of machines. They are made from C.I. accurately scraped, parallel from vee to back face, and apart from their use as bedding blocks, the back face is used with a micrometer to check parallelism of ways during the process.

In Fig. 8, Plate 2, we have a most useful bevel gauge consisting of a cast-iron block 18 in. long by 2 in. by 1 in. thick, with a tee slot to carry clamping screws. Two thick bevel blades are provided with 45° and 30° ends. This application suits a grinding machine with reverse 90° bevel and one flat way.

The next application (Fig. 9, Plate 2), shows it set up for a slide with square edge and dovetail.

The next application (Fig. 10, Plate 2), shows it set up for a double dovetail slide.

In Fig. 11, Plate 3, we have dial indicators or clock gauges. These must be kept in the best of condition and for all the finer measurements, such as truth of spindles, they should be graduated in tenths of a thou.

The commercial clock gauge stand and rod are seldom sufficiently robust, because so frequently the clock gauge is used at the extreme end of both rod and pillar. The one shown on this slide and the next are specially made with heavy bases—the pillar is $\frac{5}{8}$ in. dia.

and the rod is ½-in. dia. Note also the locking knob which really does lock.

Again, when taking trammel readings, the bar supporting the clock gauge must be rigid and a tapered rectangular bar is sometimes the most suitable, or a tube for rigidity and light weight.

That we must avoid sagging in turn-over measurements will be more readily understood when we remember that a 1-in. dia. steel bar, 12 in. long, gripped horizontally, sags between a ¼ and a ½ thou.

Fig. 12, Plate 3, shows a similar gauge, but the triangular base allows it to span awkward situations, and the pillar can be fixed in any one of three positions : Pillar dia. ⅞ in. ; rod dia. ⅝ in.

Note substantial locking handles to cope with long reaches.

A set of plug gauges and reamers for the various Morse, Brown & Sharpe, and New Standard Tapers, should be provided. Test arbors for truth of spindles with taper holes are also needed. These are simple devices, but, I would like to emphasise that they must not be any handy reamer or boring bar, but should be specially made, hardened and ground, and safely stored.

This point of storage leads to the necessity of : A proper place to keep this accurate equipment ; a place for drawings of machines and parts ; a place for instruction books and spare part lists.

It is an advantage to include in the maintenance section a number of good machines and skilled machinists to produce the repair parts, except those which can be purchased more economically.

Some special parts or operations will remain to be done by the toolroom or on production machines.

The progress department will deal with such needs expeditiously, as their interest is to assist in keeping machines in use to maintain the regular flow of work.

There still remains the final test of the machine under power, and test pieces should be machined to prove that the built-in accuracy remains under the stress of cutting.

Costs of Overhauling Machines.

These must depend largely on the size and type of machines, but as a matter of interest and as average costs for material and labour only—on-costs varying in different plants—the following can be cited :—

Such machines as :—	
Combination Turret Lathes Plain Grinding Machines Potter & Johnston Automatics Medium Horizontal Milling Machines Heavy Radial Drills	Can be completely overhauled for a cost of £30 to £50.

With these examples we can now turn to *special ways and means.* Special processes and methods of maintenance are to be taken

advantage of, or devised. For example, worn parts can sometimes be built up with deposited nickel or, where running surfaces are needed, built up with chromium. An expensive part can be salvaged economically in this way. Such deposits require to be ground with special wheels, recommended by the firms who carry out these processes.

An example of special maintenance of peculiar interest is the lubrication of some Potter & Johnston semi-automatics, used for turning and boring cast-iron liners. The turret slide used to wear rapidly with the cast-iron dust, which mixed with either oil or grease, made an excellent lapping compound, although the slides were dismantled and cleaned weekly. The maintenance men now use powdered graphite, brushed on dry, each week, and get twenty months service, day and night, against six months when oil or grease was used. *These two points will create an opening for discussion of various ways and means.*

What of the men who do this work? In these days, we shall have to search for them, and we shall also need to train them. The best of our apprentices, with good machining and fitting training, should be used to augment the squad. The clever ones are not the most successful, rather those who have an inquiring intelligence and are good with their hands. The lad who asks to get on the section, generally makes good, for, without a liking for it, there is little hope.

It is not always appreciated, that with modern machines these men are often dealing with new mechanisms, new assemblies, not some task done day by day in production. The bits he has taken to pieces have to go back again; there must not be any left over. The clearances have to be right; the timing has to be reproduced, and often without a very good instruction book from the makers. Meanwhile, the progress department must have their machine by a certain time, so it's often a thankless job.

What of the nurses? Well, the foremen and men should nurse their machines as much as anyone. A very large percentage of maintenance repair is needed, because lubrication has been neglected. Could we not have men trained and equipped with the right oils, greases, oil-cans and guns, to do the routine lubrication, and relieve the men? It is a point for discussion.

Now, let us see how machines sometimes get nursed.

A Word on the Electrical Side. With so much electrical equipment incorporated in machine tools, maintenance responsibilities are increased and some imperfections of construction are encountered. Routine maintenance must include: Blowing out of motors, cleaning of motors, replenishing bearing lubricant, insulation tests, attention to starter contacts, tightness of screws, etc. The methods and

periods will vary somewhat with the conditions under which they work.

A few points which arise on machines with direct motor drives, in the average machine shop can be mentioned. Layout of cables needs to be examined. So often they are passed through drilled holes in castings which are left with sharp edges instead of being well radiused. Motors should be protected from C.I. dust and oil. Apart from direct splashing of oil, the atmosphere of a section of heavy duty machines using straight cutting oil will affect motors which have windings protected with bitumen compound, and these will require an overlaying coat of oil-impervious varnish.

Rubber-covered flexible leads to allow for movement of slides with motors attached are quickly attacked by oil or cutting compound. A relief from this trouble is, however, in sight, as the cable makers are now in a position to supply cable insulated with a synthetic rubber called " Neoprene " which is proof against oil at reasonable temperature. Trials are also being made of vee belts, with Neoprene as the covering instead of rubber, as a protection against oil which rapidly perishes the latter.

Oil also attacks main leads in tubing, if joints are not made with impervious jointing. The vapour, if it can find its way into contactor starters, will cause sticking of the magnets, necessitating cleaning and preventative measures.

Improvement. When all this has been said, there still remains a question. How are we going to improve the breed ? To reduce the necessary maintenance ? When will the engineering body be more perfect ? Well, it has its birth in the machine-tool maker's shop, so we may well ask what is he doing about it. Really, he has done much, though there is still a lot that could be done. Where we are willing to pay for it he has given us covered slides on certain machines and centralised lubrication and automatic lubrication. I would put these two items first by a long way.

The wear on slides is caused by the swarf, shot from previous shot-blasting, sand and scale from castings and forgings, dilution or washing away of oil, the best lubricant, by the cutting coolant, damage by impact from parts or tools. Covered slides afford a protection against all these and with automatic lubrication we have a simple but effective cure for the major cause of wear, loss of rigidity under cut and accuracy of operation. I can speak with experience of the first two turret lathes to be sold by a well-known maker with this refinement. After working them day and night for five years, the slides are still in splendid condition. I think it is worth while mentioning some of these devices.

It is very gratifying to find boring and centring lathes fitted with good protection, as they depend entirely on the good fit of the slides

for producing good work, whereas the turret lathe is, to some measure, helped by pilot bars and roller steadies. Other British manufacturers are providing these facilities and there are also some noteworthy American examples.

Hydraulic operation of certain machines has proved a help and, where maintenance proved a little troublesome on some grinding machines, it is now met by changing the oil at intervals of about three months, and adding further safeguards to prevent the coolant from getting into the operating oil. Anti-friction bearings are more widely used and not only increase life, but reduce the lubrication problem at out-of-the-way situations and, when they do need replacement, such replacement is quickly and easily effected.

Preloaded ball bearing internal grinding machine spindles are now available and eliminate the incessant maintenance inseparable with plain bearings for high speeds. Interlocking devices to prevent accidents to men and machines are now more general and it would be well if these were considered under the same category as guards in the new Factory Regulations.

Ammeters to show the load on the machine, are now to be had on many machines which are motor driven. These will, particularly on heavy loaded machines, indicate to the operator when tools are failing and reduce maintenance due to overloading. They also sometimes show how lightly a machine is loaded, demonstrating the need for smaller motors which, running right up to maximum load, will show a better efficiency and power factor to reduce the bill for power.

Deficiencies. On the other hand, the machine-tool maker can still reduce plant maintenance, and in consequence, increase productive efficiency. He can give us larger trays or pans below the machine for oil and swarf, and a good get-away for the swarf, preferably to an extension of the pan, so that swarf may be removed easily and without spilling.

Oiling diagrams on plates on the machine itself, with a guide as to the frequency of attention required to the out-of-the-way places, which may only require intermittent oiling. Also the correct oil to use if it is special.

Filtering arrangements are inadequate or inaccessible and again easy cleaning is seldom studied. In some cases machines are too compact and parts requiring adjustment are too inaccessible. Might I suggest that a designer should spend a fortnight each year with one or two of the service men in plants up and down the country? Pumps are frequently too small and too vulnerable to chips and swarf. Provision of eyebolts or holes for same to facilitate lifting heavy sections of machines, often do not exist.

Better fittings should be provided for the supply of soluble oil or other cutting lubricant. The fittings and pipes are frequently

too small, leak, and are insufficiently robust to maintain a set position. Adjusting screws and clamping screws frequently work loose, because good locking arrangements are not provided. Keyseats for keys, both parallel and woodruff, should have well radiused corners and the shoulders of shafts and undercuts at shoulders should be well and smoothly radiused, to prevent fatigue fractures.

On motor driven machines, we often find provision made for fitting the motor, but none made for fitting a starter or push button control within handy reach of the operator. A well positioned facing to suit this purpose could easily be incorporated in the head casting, to save time, money, and give a better appearance.

On automatics we need in all cases shearing pins or slipping clutches in both feed and rapid traverse mechanisms. Splash guards are seldom adequate, in either size or envelopment, to retain the oil within the catchment area of the machine. We ourselves have lately improved certain chuck guards by adding flexible extensions of Neoprene, so that they drag on the slides but cannot jam. That is another use to which this and other rubber substitutes can be put.

I believe, in many automatics, it would be useful to have a means of draining off cutting oil through a large cock in the base by suction and to pass it through a portable centrifuge to separate the fine swarf that accumulates.

Instruction books and spare parts lists are improving and the example set by some German and American makers could well be followed. I have one service manual with me which could be examined as an ideal in this respect.

I would like to illustrate a few of these points.

In Fig. 13, Plate 3, we have a type of milling cutter guard for horizontal milling machines, one which we have found most easily adjustable, most easily swung out of the way for setting, and best liked by the men. It swings on rods clamped to the head of the machine. How much simpler and neater would be the fixing and the appearance if the provision had been made initially on the machine head.

Fig. 14, Plate 4, shows a guard for a vertical milling machine. Again the rods which support it had to be fixed by brackets, which had been better incorporated in the design.

As the guard itself is a maintenance man's addition, it deserves description. It consists of a ring with two long outstanding lugs which enable it to be adjusted. In this ring is clamped a sheet metal guard, a cylinder with a section removed. Adaptors will enable various diameter guards to be quickly inserted.

To guard the cutter on a vertical mill where a complete pass over is needed, the type illustrated in Fig. 15, Plate 4, shows promise. Here the guard is in two pieces of angle shape, adjustable in and out to form an inverted channel. Again, upward adjustment is

provided and the rods on the head are the primary support. Since the photograph was taken, the slots in the side have been filled in.

Now I wish to present another line of thought. Machines do grow old, and sometimes too old to repair or overhaul. How do we measure this oldness? Not by age—only by usefulness. Some measure of this can be seen from the "Sanction for Overhaul" sheet mentioned earlier in this paper. The actual overhaul might, however, impair its usefulness. Let me explain this apparent paradox.

A combination turret lathe with uncovered bed, will, on general work, do reasonably good work for six years (or three years if we are working day and night shift), and I prefer to reckon this way. After its first overhaul, it will last another three years day and night shift. After its second overhaul, another three years day and night shift. That is, nine years day and night shift.

Now, in these two overhauls, a good deal of metal has been removed from the bed, the saddle slides, etc., and particularly on the saddle we have reduced certain sections as far as is safe, may be almost breaking through, and a third overhaul will mean a new saddle. The reduction of surfaces has brought rack and gear centres closer, and more new parts are needed here and there, and this third overhaul may become a very expensive one.

It might be the fourth, not the third, but you see my meaning; wear has decided its usefulness, the machine is threadbare. Again, maybe a new tool metal has proved advantageous in reducing cutting times, but would require a more powerful machine, so that you decide not to overhaul again

As time goes on, fashion changes. Your manufactured goods may also have changed. To meet power to weight ratio, you may now be using higher tensile steels and alloys, and the machine may not be adequate for the greater stresses and strains imposed in machining such materials.

The very process may be changed. What is the good of overhauling a cylinder grinding machine if you have adopted or intend to adopt honing? Why overhaul the old steam engine if the Electrical Supply Co. are waiting in the hall to offer you electricity at a farthing a unit? I'm afraid that is rather a rosy dream. The gearbox manufacturer would not overhaul his spur gear cutting machines if his new designs are to include exclusively helical gears.

Sometimes accuracy decides the usefulness. New accuracies found necessary to meet interchangeable assembly in place of old time fitting methods may settle the age question. This particular question of usefulness should always be reviewed twice. If the machine itself is not accurate enough, will it work with an accurate self-contained fixture, the machine only driving the boring bars,

etc., presuming that it still possesses the necessary capacity and functions for spacing, travel or traverse ?

This leads us still further. If a firm has the spare room, only really useless machines should be scrapped. The others should be stored for the emergency job or special purpose machine which may be required. For example, the following adaptions come to my mind : two old internal grinding machines now used for a light honing operation on the arc-shaped palm of a rocker arm. Another such machine is used for lipping cutting tools. Two very old pillar drills are set up beside two double spindle drilling machines and equipped with countersinking cutters, which are used by the operators whilst the spindles of their main machines are feeding.

An old light three-spindle drilling machine had the heads removed. One of these, motorised and fastened to a fixture, centres our crankshafts. The other two, motorised, just suit a light single-speed drilling operation in an assembly line. An old horizontal drilling machine, with the addition of a plate for table and a circular saw on the spindle, removes clamping lugs from light aluminium castings after these have passed the operation where the lugs were needed. All the same this store of old machines should not become a hoard. A yearly review by the plant, production, and tool departments, is needed, so that it does not become an encumbrance.

Finally, when selling machine tools, watch their market value. If they are very old, or obsolete, and only fit for scrap, and you are to get next to nothing for it, then it should be remembered, for instance, that the tee-slotted table of an old boring machine may form a useful sub-table to take an outsize job on a milling machine, or make a useful base for a jig. In this way you can gain a piece of auxiliary equipment worth more than the money you would have got for the whole machine.

We have now, I think, traversed the life span of a machine and, in bringing this paper to a close, I would like to acknowledge the help of Messrs. Ward, Herbert, Archdale, Burton Griffiths, A.B.M.T.M., J. Lang & Sons, Ltd., Albion Motors, Ltd., and the Editor of *Machinery* for information, material and slides used for the lecture ; and also to Rudyard Kipling for his inspiration to a maintenance engineer. It was he who said : " I keep six honest serving men. They taught me all I knew—Their names are, What and Why and When, and How and Where and Who."

Discussion—Edinburgh Section.

MR. PEET (Section President): Mr. Mallett has taken us a very interesting and absorbing tour through the "Maintenance Hospital" to-night, and we have seen all his very "hard beds" and what all his Chinese doctors and nurses can do, but I think he has left out an item there, and that is, the "temperature chart" is not over the bed, and by that I mean the repair sheet. The production engineer will need that and he will also want his machine back quicker than he can get it from the repair shop. I would like to have seen a similar thing shown here. We saw the machine "overhaul and sanction form," but to my mind, to follow that through, the production engineer will send a repair card to the maintenance department with what the symptoms are, and he will want that machine back as quickly as he can possibly get it. That is a point that I think was missed out of the lecture and to my mind, as a production engineer, is one of the chief ones required in connection with maintenance cost, if, as Mr. Mallett says, in China the doctor there is paid to keep the patients well and not paid when they are ill. I would like to have your views on that.

In connection with the grinding machine you showed with parallel slides, do you consider the methods you have shown to-night to be the best for testing the height of centres, or do you think there is an easier way in which it can be done? I believe you have shown the more formal way of doing the job.

MR. MALLETT: The sanction form is for the overhaul of the complete machine. It is used when we consider that a machine has reached a stage that we must take it out of a plant and completely overhaul it. The emergency repairs are dealt with in a way similar to that which you have outlined. We actually use a small card, and all foremen have a number of these cards, and it has on it attention required to machine number so and so at such and such a time, and so on, and a brief note of what is wrong if it is known. Actually it is more than that; it is a general maintenance card, because it applies not only to the millwright, but also to the electricians, joiners and plant department themselves. In other words, there is available something like an army postcard—you cross off the unessentials, leaving the essentials. That goes to the foreman millwright, or the foreman joiner, and he gets on the job right away, for these things which must be attended to at once. The complete overhaul, however, entails consideration of costs amounting to £30 or £40 labour and material and it may total £100 or so, with oncosts.

The grinding machine test! I presume you are referring to the

universal machine and the test to make sure the centres are in the same plane. There is one simple test on the right hand side of the chart where the table is flat, when you only use a clock gauge. On the other side, where a vee-shaped table is shown, the use of a level and discs is applied. Should the machine have a projection from the side that can be used as a shelf for a clock gauge, then readings can be taken from this datum direct on work centre test mandrel, and then on the wheel spindle as it is traversed on its own slide, and this is sometimes a simpler method. That may be the one you have in mind. It wasn't shown as I had to take the chart as illustrated when making the lantern slide. There are certain machines where the tests are more simple, but the principle remains the same, that both axis must be the same or the machine won't grind tapers correctly. It is surprising the number of people who do not appreciate it.

MR. MARSHALL : I would like to ask what type of motor is now being used and incorporated within the construction of machine tools, that is, D.C. or A.C., with variable speeds. A few of your remarks are no doubt applied to a plant where there are a very large number of machines. You were speaking of tools that are removed bodily into a repair bay. That is all right in some cases, but supposing we take the small machine shop, with 30 or 40 machines, you have got very little room and it becomes a difficult matter. Also, in connection with the tradesmen carrying out this work, a great deal more could be done to-day in regard to the training. I know one case where youths that are starting their apprenticeship on this type of work go on for six months and they are actually put through what you might say is a model machine shop, and every week they are definitely noted as to their capabilities on various work. At the end of that six months they are transferred to the department that they show most aptitude for, or else not taken on. I believe it pays very well. There is another point in regard to the maintenance of machines. What degree of accuracy would you work to before you would take a machine out of production, and also when it is put back into production, what degree of accuracy should it show ? There is this figure of a thou. that is more or less in the air. This question of safety guards. I am not quite clear on the latest developments. I think there is a great deal to be done in protecting the user and the owner of the machine. I think the machine builders should be made to provide adequate guards for the safety of the user. There is another little item I would like to mention and that is whether you have had anything to do in connection with this extra rate that has been levied by the trade unions on maintenance work in connection with machine tools.

MR. MALLETT : With regard to your question, Mr. Marshall, on the type of motor on machine tools, I am not an electrical engineer

to speak with complete assurance, but if you have got a plant in which you have got nothing but a D.C., supply, you will use D.C., but you will find it is very expensive for equipment, as a rule, unless you are forced to use it for some other process. I would think that for most of the smaller plants, the A.C. motor is being used. If you take drilling machines where the motor is built into the spindle and the rotor actually forms part of the spindle, then it is an A.C. pole charging motor that is used. On motorised grinding machines, A.C. motors are used, and they will drive the hydraulic pump—and only on the work table itself do you find a D.C motor, and with this you generally find a Ward Leonard set with an A.C. motor driving the dynamo to give you D.C. current for the workhead motor, as you require a variable speed to get the correct work speed when grinding.

MR. MARSHALL : What I was really trying to bring out was, do you think it possible to use now an A.C. motor for variable speeds, to cut out a lot of the change gears used to get variable speeds ?

MR. MALLETT : I would say " yes " if you can afford the money to pay for that variable speed A.C. motor, because that is an expensive motor. You would have to weigh it up for the particular proposition you have in mind. You can get a variable speed A.C. motor, and that is as far as I think I ought to answer you there, because you require to consult an electrical engineer with the problem.

The question of removing the machine from the plant: in a small shop, of course, you wouldn't do it. I suggested it was better to do it, and I think it is whenever possible. You can take it where all your appliances are ready; you have got all your men there, your equipment ; also you have got the men for turning, shaping and grinding parts that have got to go together. If you haven't room and it is a small shop, you must do it in its place, but you will find it more difficult as it is inconvenient and you are working in someone else's way. If you can possibly manage it, get it out of the way, where you can concentrate on it.

Tradesmen and apprentices ? I presume that you are referring to the fact that we must make a good tradesman by training our apprentices, and you can mention a small model machine shop into which they went to start with. I wasn't clear whether you were referring to its effect on a maintenance job.

MR. MARSHALL : It was actually for machine tool fitters.

MR. MALLETT : I would say it was a good idea. I know firms who have their own apprentice training departments. The apprentices go into this small department and they are given a certain amount of fitting. There are also a few lathes, milling machines and drilling machines, and they do simple work, but actually production work which they are capable of doing, and from there they graduate out

into the other sections. That is just an example of a scheme for apprenticeship, and I quite agree with you that we need it badly. If you get a boy who later on is doing well on turning, milling and possibly grinding and has done a certain amount of fitting and assembling, and has shown an aptitude for it ; a boy with good hands, and who says, "I would like to get on the maintenance squad—I like the idea of doing maintenance work," that is the boy you want to get hold of, and you generally find that he is the boy who makes good on overhaul work.

Coming to the degree of accuracy before you take a machine out and after you put it back! It entirely depends on your production. You might be able to leave it in till it gives only 10 thous. accuracy and still be good on the job. But if a gear hobbing machine spindle runs out of truth more than ¼ thou. you may have to make a new one, so it entirely depends on your product.

All safety guards are for the protection of the man. The guards I was referring to when I mentioned splash guards, and those to cover the beds of the machines, were to protect the machines and keep the floor and operator clean, but the milling machine guards, and similar guards, are for the protection of the men, and you will find in the new Factory Act that machines sold after a certain date are to be provided with safety guards ; it is not to be left to chance.

MR. BURNS: I was fortunate enough to work alongside Mr. Mallett some time ago, and I knew that he was well equipped for dealing with this problem of machine maintenance. During the course of his lecture he mentioned " in our Works," and I think it might help some of us to appreciate what he was dealing with if he could just tell us what Works he was referring to. In case any of you were wondering, I will make a guess : I think it was the Albion Motors, Ltd., and if so, it is a very well equipped factory. It possesses some of the finest machinery in Scotland, there is no doubt on that point, and it gives an indication to Mr. Marshall, whose points I could appreciate, that he was looking at the matter differently from the lecturer, who was dealing with the maintenance of a very up-to-date machine shop. The work of the maintenance engineer who is dealing with a large factory making a large variery of, say, rubber products is entirely different from an up-to-date motor car machine shop.

That was a very interesting slide of the damage done to machines by operators using the hammer carelessly, and knocking the mandrel out of the job on a lathe bed. I think the only cure for that is to use the hammer on the operator. At the same time, he is a very good friend to the maintenance engineer !

Another interesting thing I noticed was the building up of worn parts by depositing nickel and chromium. That to me is quite new, and I can appreciate its value. I daresay it is largely a question of cost as to whether the deposit of nickel would be worth while ;

possibly you can say, Mr. Mallett, something about that, as to what the cost of depositing the chromium and the nickel would be.

Regarding guards for machinery, that is a very difficult point, because one would think sometimes that an operator was trying to commit suicide, and there are no guards one can really provide which will prevent a man putting his finger where it is not supposed to be. Even with that vertical milling machine, there is a small opening in the guard, and you will find a fool come along and try to pull out a little grit with disastrous results. I would like Mr. Bennet to tell us of an experience he had in his works. It is a case which happened recently, relative to this question of providing guards for machines. The opinions of the judges were interesting and it means you have really to guard against, not the normal man, but against the idiot. That is the position nowadays, to provide guards against these people—I do not know that it is possible really, and I would like Mr. Bennet to give us his illustrations; it would be very instructive.

MR. MALLETT: The maintenance question I have tried to deal with in broad principle; if you look back on it I don't think I dealt with details very much; I couldn't have told you about it all. This is only one section of my work, and I couldn't tell you the exact figures to which we work in all cases, that is, from memory. If the men are trained in this work and they have had previous good training and experience in fitting, the principles can be applied, I think, even in the small shop. Some thirty years ago, I was with a firm where we had two works, and one works was burned almost to the ground, but the machines were not completely destroyed. We had to rebuild them, for nobody could provide them, as we made our own machines because they were special. It was a very interesting job, and in those days we didn't have the clock gauge; we used a scribing block, and we used to say it sang evenly when the surface was true. We would also use feelers as "Go" and "Not Go" gauges with the heavy scribing blocks and trammel bars. I drew a good deal on my old experience on some of the points to-night, and if you apply the broad principles the details will look after themselves.

For depositing nickel and chromium, I couldn't give you costs, except to say that if you have a worn part in the middle of a big spindle which is expensive, it will always pay. I can tell you that chromium-plated plug gauges last about thirty times as long as ordinary case-hardened plug gauges, and the firm who does the work is well known. In connection with guards, you are quite right and I would like Mr. Bennet to tell me his story.

MR. BENNET: This is not exactly a story, but a somewhat unpalatable fact, and arose from an accident that happened in my works, where on a power press a girl was doing a job, and the job

clogged, and to try and free the clog she put her hand under her guard, levering the guard up, got her job free but accidentally at the same time depressed the pedal and the tool came down and took off the tips of two fingers. About six months after that the factory inspector laid a case against us in the Edinburgh Sheriff Court ; the sheriff decided against us and fined us £20. We thought we had got off lucky ; but on a question of appeal we decided not to, as two cases were cited against us in the court. Just recently we heard that the decision in the Edinburgh Sheriff Court has had a parallel in the Appeal Court in England.

In the " Weekly Notes " published by the Incorporated Council of Law reporting for England and Wales, dated Saturday, November 6, 1937, a case was stated by the Merthyr Tydfil Justices. The accident happened in a coal mine and the factory inspector brought a case against the mine owners under the Coal Mines Act of 1911. It appeared that there was installed and used in the mine a conveyor belt and that the rollers of the conveyor belt were enclosed in a cage which purported to shield them in such a manner as to prevent them being an object of danger to those employed about the conveyor. At certain parts of the cage there were apertures for the purpose of oiling the rollers. The accident happened when the belt conveyor was stopped and a fitter employed in connection with it got on to the bottom portion of the belt and began to crawl along it on his hands and knees towards the rollers. He was apparently attempting to discover the cause of the stoppage, but unfortunately the belt started to move whilst he was still there. A shout was heard and the belt was stopped, but the fitter was found dead between the top rollers of the bottom set at the return end. The local justices held that the fitter met with the accident when he was acting in a wrong and extraordinary manner and they dismissed the case.

The factory inspector appealed, and it came before the Lord Chief Justice and Justices Humphreys and Du Parcq. The Lord Chief Justice allowed the appeal, and in giving the decision of the Appeal Court said that the machinery was undoubtedly dangerous. He also said it was quite idle to say that the information was dismissed because the workman was acting in a wrong and extraordinary manner. *Workmen often had to be protected against themselves.* He also said he could not conceive anything more sublimely futile than a statutory provision for the protection of workmen which should leave out the particular class of workmen most likely to come in contact with the machinery. This not only shows that manufacturers who are in control of dangerous machinery have no relief when an accident happens due to faulty or indifferent fencing or guarding, but that they have no relief even when a man evades or disturbs an existing guarding system.

MR. MALLETT : Thank you, Mr. Bennet, I am very glad you put

it so clearly to us, because the safety problem is a serious thing. The law gives you no loophole and you have got to guard against the foolish as well as the careless operators.

MR. MORRIS: Have you any experience of lubricating heavy plant? You mentioned there that instead of grease you were using another lubricant—graphite. Have you had any experience with that on heavy plant, say 4 in. to 6 in. shafting? How do you think it would do in bearings of that description?

MR. MALLETT: No! I have not and wouldn't try it—unless it were slow moving. Under the dusty condition, such as I mentioned, I might try it, but I would keep a watch on it, as I have no experience of using graphite on shafting. I would be prepared to try anything if it offers a possible solution to a problem.

MR. MORRIS: Are these slides practically dust-proof and covered all the time?

MR. MALLETT: They are not covered at all. The turret moves backward and forward and comes up close to the cross slide. There is no room except for a telescopic guard with an extraordinary range which we have not devised so far. The slide for the turret is therefore exposed to a certain amount of cast-iron dust, but the cast-iron dust when mixed with graphite is not so damaging to the slide as when oil or grease is used. One might say that that was a way out, but I used it as an illustration of special ways and means because I wanted other people to tell me their ways of overcoming unusual difficulties. It is one of the most interesting points of machine-tool maintenance. I sometimes do strike a very interesting way out, but the other man's way may be quite as interesting, and such points help to build up experience.

MR. PEET: I could hardly visualise at the time you said it, that for a "Gleason" gear planer the cost of repair was £25, and yet for a "Potter & Johnston" you want £32. I should have thought that a "Gleason" would have been considerably more than a "Potter & Johnson."

MR. MALLETT: As it so happens, it wasn't because—I only give you this as my particular reason—that Gleason bevel gear generator is more of a precision machine and it is worked with oil the whole time and on clean material. It is well lubricated, and the amount of overhaul necessary was really more a question of taking up slackness in slides, whereas, in the "Potter & Johnston" Chucking Semi-Automatic, in addition to taking up wear on the slides, which was considerable after handling rough stampings and castings with sometimes intermittent cutting, the spindle bearings had to be done, a certain number of gears had to be replaced, and the clutch on the spindle, and of course, when you have finished that and assembled your machine, you have always got to rebush the turret. In a way the repair to the "Potter & Johnston" was an

overhaul for wear and accuracy, and the repair to the " Gleason " was what you might term an overhaul for accuracy.

MR. PEET : I thought the " Potter & Johnston " would be a machine you ran to death every time.

MR. MALLETT : You certainly would run a " Potter & Johnston " hard, but I do not think anyone runs a " Gleason " to death, unless they are producing poor class gears, then they might, and certain parts of the machine would wear badly. We have not found it so. I think that is the real reason as we were actually not doing very heavy work on that " Gleason " machine.

MR. ELVIDGE : I was very interested in your lecture. You said that when a broken part of machine tool is discovered you do not always replace it with the material with which it is originally made. That is really true of a whole lot of cast parts. Machine tool makers put far too much light cast iron on their jobs, and parts have to be replaced, which we would otherwise never dream of replacing. Another thing, the gentleman on my left rather upset me when he said he knew which works you were talking about and then spoke of Albion Motors, Ltd. Then I understood you to say that you reconditioned your machine tools and made them last 9 or 10 years. I always thought that a modern factory threw their machine tools out every three years. Would you please explain that.

MR. MALLETT : I absolutely agree with your first remarks, Mr. Elvidge.

To answer your second remarks on the average age of machines and the fact that we overhaul machines to make them last nine years, I couldn't give you an average of all our machines, but it is a fairly big figure. I would refer you to the inventory that was taken of machine tools in America in the various trades, the motor car trades, heavy iron trades, published in " American Machinist " some six or seven years ago. If you can get hold of an " American Machinist " file you will get it. I just can't say the exact percentage from memory but nearly the half of the machines in the United States were ten years old. Take a planing machine, that will probably last up to 30 years ; and take the other machines I mentioned just now, combination turret lathes, and so on with the uncovered beds. You can recondition those and make them last nine or ten years, but the machines with covered beds, those haven't shown wear after ten years.

MR. ELVIDGE : My point was not that they won't last that time, it was that they don't work so quickly and economically as the machine which was designed yesterday or a year ago.

MR. MALLET : In the case of certain machines, you are right, of course, single purpose and grinding machines, drilling machines, gear-cutting machines and automatics, in some cases but not always,

because with automatics you are working most frequently on a group system, and as long as you have the floor space, the time the machine takes to produce the part is not so important, as you only pay for handling time.

MR. ELVIDGE: Is an American shaping machine bought to-day no better than one designed ten years ago?

MR. MALLETT: For general work there is not a great deal of difference. Of course, for real production work, most works would probably be using a milling machine. On milling machines, I believe your point scores most, inasmuch as if one could afford it, one would always have the very best milling machine, hydraulically operated, on almost every job. But many other machines do not need changing so frequently.

The proceedings concluded with a vote of thanks to Mr. Mallett.

Discussion—Glasgow Section.

MR. J. LANG (Section President): I am reminded of a story. There was a Padre in saying grace after meat had two graces; when he had a real good meal he began "O Bountiful Provider" but when it had been tatties and herrin' his start was "For these, the least of Thy mercies." I think, gentlemen, Mr. Mallett has given us bountiful food for discussion.

There are only two points I want to mention. The first is, I appreciate very much indeed Mr. Mallett coming here to talk with us. The slides which he showed on lathe beds, and how they were misused, I think will have appealed to you. The other point is, I agree heartily with Mr. Mallett's point regarding liaison between designer and user. I think, perhaps, that is now taking place. Certainly we feel that we owe a very considerable debt to the user, but I don't know whether that was true ten or twelve years ago. Whether the user realises it or not, he is really the designer of the machine tool, taking a very long view, because the maker must supply what the user is prepared to buy, but I do agree whole-heartedly that that liaison is very desirable.

MR. J. WRIGHT: I have got to thank Mr. Mallett for his excellent paper and for the thorough manner in which he dealt with his subject, therefore I don't propose to criticise or really ask him any questions but rather to supplement some of the things he has said. Regarding design, I would add to what he has already said the fact that in my opinion there are far too many flat surfaces on the average machine and, if some considerations were given to such simple things, there would be less inducement for leaving spanners lying about or for the harbouring of swarf. I would, however, like to know from Mr. Chairman or Mr. White, why, to assist both the plant maintenance man and the quality of the work produced, rollers or balls are not used in slideways rather morethan they are. I, personally, have made one or two applications with success and to be quite frank, I don't know why they are not incorporated in the average small machine tool. Take a tapping machine, for instance, where the operator has sometimes to feel a fine thread being cut, the friction of the slide is a very big factor,and I can assure you that the judicious application of ball bearings to the slideways is a very big help in that respect.

With regard to the question of what we ourselves can do to help the plant maintenance man, I was surprised that Mr. Mallett did not mention discipline, because I think discipline plays a very big part in the condition of the machines and tools and how they are treated. You all realise the amount of strain that is set up when

running, say, an automatic machine with dull tools—that was either not mentioned in the paper or only touched upon. The condition of the tools plays such a big part in the condition of the machine that it is worth consideration. I had one or two people who, at one time, were very proud of the fact that their tools stood up for two months or ten weeks without grinding. Now the amount of damage done to slideways, cams, cam rollers, spindles, and all the accessories as a result of dull tools is considerable, and it only needs to be tested to find out the saving in plant maintenance cost that will result from the periodic grinding of tools to a predetermined schedule. The result of dull tools is that you have to give your machine a more frequent periodic inspection than would otherwise be necessary.

Another factor causing machine breakdown is where a machine has a double drive, one to the work spindle and one to the feed. Often, as you know, the spindle belt breaks and the feed continues. Something might be mentioned in that direction. The spindle drive and feed drive should be on one common shaft, so that if the belt breaks, the whole mechanism stops. This would prevent machine breakdown.

Yet another point is the question of the accuracy of the work spindle. In many cases, the accuracy of the work spindle is fundamental, and yet we often have the pull of the belt on the same bearings, which is the biggest factor causing the inaccuracies and calling for repeated overhaul of the spindle bearings. This could be overcome by an additional bearing and dog driving the spindle. The results are so beneficial that I often wonder why it is not more generally incorporated in the average machine tool.

MR. MALLETT: I must agree with a number of the things Mr. Wright has instanced. With regard to the question of anti-friction slideways, you mentioned the use of balls and rollers, and you have asked Mr. Lang and Mr. White to respond to this point, but I might also give one application which is proving very useful, namely, in the cutter grinding machines where the table runs on a roller track. Heavy inserted blade cutters can be oscillated backwards and forwards with just a twist of the finger and thumb. Discipline? I did not mention that. I did, however, stipulate "advisory measures" which, as a rule, are as far as plant dept. or maintenance man can go. Discipline certainly requires stressing, and I am glad you mentioned it.

With regard to breakages where the feed goes on, particularly where the machine has two belts. That is an unfortunate part of the design in that machine. If there is no common belt drive to the two motions, spindle and feed, then there ought to be shearing pins or slipping clutches, whichever is more suitable. Going a stage beyond that of the ordinary drilling machine, and coming to the very much more powerful machines, such as chucking automatics,

then if the feed goes on when the spindle stops the results are disastrous. Your problems with these belts, with the need stated in the paper, for slipping clutches, go together, and such remedies are well worth trying out to lessen breakages due to jamming up. Concerning the drive to the pulley which causes wear and inaccuracy due to belt pull. On many machines this is now provided. Many centre lathes, turret lathes, drills, etc., have separate bearings for the driving pulley. There are a lot of other machines which ought to have similar provisions. In some cases where the driving pulley comes between two bearings, it is not usually quite so bad. These are both good points to record and watch.

MR. LANG : With reference to Mr. Wright's question regarding the application of rollers to slideways : The reason my firm do not use rollers on the guiding surfaces of beds from 12 ft. to 35 ft. long must be obvious. We have on occasion used rollers on short slideways that could be completely covered. A very successful application I can think of was to the cross slide of a lathe producing glass bottle moulds. The work was elliptical in shape, the variation in diameter at 180° being .0015 in. and with the cam operated roller cross slide this very small variation was produced successfully.

MR. T. WHITE : I would like to congratulate Mr. Mallett on his paper and on the care and thought which he has given to this subject, which is one of vital importance to engineers to-day. Maintenance of machine tools can be looked upon from two points—the maintenance from a production point of view and maintenance from a depreciation point of view. Mr. Mallett seems to have strong views, and probably naturally, on the reconditioning of machines. He actually mentions going to four overhauls. Take a No. 9 Combination Lathe, which can be purchased to-day for £900. The depreciation which a firm allocated in their account does not necessarily mean that the same depreciation is allowed by the Inland Revenue, as the Inland revenue are going on their own figures, and therefore, if a machine has run ten years, night and day, it has practically exhausted the depreciation allowance given by the Inland Revenue and taking the figure of a new No. 9 at £900, running night and day, it means that the Inland Revenue would allow £135 per annum. This might be written off by the users in their accounts and not allowed by the Inland Revenue in theirs, and, therefore, the firm are paying Income Tax on this £135, at 5/- in the £, which is roughly £34, making a total of £169, to which would require to be added the cost of re-conditioning.

Mr. Mallett gives a figure for a No. 7 Combination Turret Lathe of £50, and I do not know what oncost or anything is allowed on this, but even taking it at his own figure on a No. 9 Combination Turret Lathe, with the value of the work at £80, and adding this to the £169,

we get a total of £249. In taking to-day's second-hand value of the machine at £350, it means that a new machine can be purchased for a payment of £350. You will see that the saving effected by pure chasing a new machine would wipe out the cost in little over two years and it therefore seems to me an uneconomic proposition to carry out complete overhauls indefinitely, my experience being that no matter how thorough an overhaul is made, the metals are tiring and wearing throughout, and while a complete overhaul does bring a machine to a certain point of efficiency, I would not agree with Mr. Mallett that this reconditioned machine would give the same number of working hours as a new machine. My experience is that when the market is low for second-hand machines, then recondition within limits, but when the market price is good, dispose of the machine, and replace it with a new machine and so maintain the maximum depreciation allowance. To give a recent example—I disposed of a Cincinnati Milling Machine for £430, which had, allowing for nightshift, done 20 years' work, and was therefore practically past its depreciation stage, and replaced it with a new machine at £600, which enables us to earn again a depreciation allowance for a payment of £170. The new machine was, naturally, more modern in position of levers, feeds and suitability for motor drive than the old machine and, therefore, in considering the re-conditioning of machines, it should be done in its broad sense from an economic point of view—when it pays to recondition and when it pays to sell.

MR. MALLETT : Actually your exception really fills in some of the particulars which often have to be considered when going over the sanction sheet. When the sanction sheet is drawn up, it also has sections, you will remember, for present book value and market value, cost of and relative production value of a new machine of the same type, and its efficiency and productive earnings which would all have to be weighed up. I actually mentioned nine years as being the life of certain machines. This, I believe, coincides with yours as being a reasonable figure. I did not intend anyone to think of me as being unreasonable and expecting a machine to be run to death. Depreciation figures must be allowed for. I did not go into figures because I saw an accountant who told me to steer clear of them. I thought of bringing a book on depreciation and income tax allowances which is half an inch thick, but I did not think it worth while for this lecture. I must thank you for your own admirable illustration on the spur of the moment. These sanction considerations would afford in themselves a basis for a large discussion.

I missed one point of Mr. Wright's. You mentioned the dull tools, Mr. Wright. I am sorry I did not deal with your point. That is a big factor and whereas I showed in a slide of one machine, you have an ammeter; this would give you a guide when tools were

becoming dull. Obviously there are many cases in present day machines where you have not got that guide. It is an advantage applicable to the motor driven machine. On the particular machine I showed with that ammeter, the people who are using it have, as a matter of fact, recorded few overloads. With sharp tools, the machine runs well within the capacity of the motor. However, the point you mention is a very useful one indeed and it is a good case for the motor driven machine.

MR. J. MCFARLANE : Mr. Lang used such an apt illustration at the beginning that the little story I had prepared concerning a sausage roll and the amount of meat it contained can be reserved for another occasion. Incidentally, concerning Mr. Mallet's reference to a Chinese doctor, I think some of them to-day must be having rather a thin time of it.

Naturally, a lecture of the description, covering so much ground, appeals to different people in different ways. The part which had a special interest to me concerned the test applied to the machines. I noticed in the slide for Test No. 1 of the vertical milling machines, that two clock gauges were applied simultaneously. I was specially on the look out, because I had read an advance copy of Mr. Mallet's paper, and he only mentioned a clock gauge, and I was ready to challenge the point, because it will be known to most people that the arbor must be true at two points in its length before the truth of the spindle can be ensured. It is quite possible to have a condition of untruth which might register truth at one particular spot. That would be a case of angular untruth with the axis of the arbor crossing the axis of the milling machine spindle.

With regard to the faceplate test, I would say that such was a test for wobble and, therefore, for angular untruth. Parallel eccentricity not shown up by the faceplate test, could be tested on the periphery of the faceplate itself, just as you could test the same type of untruth at the two points of the arbor, the same amount of untruth being registered simultaneously in the two clock gauges. Axial slip, of course, as Mr. Mallett showed on the slide, must be taken as near the central axis of the spindle as possible. Concerning other tests of straightness, parallelism, and squareness of the moving parts, I would like to ask Mr. Mallett if he has had any experience of the Hilger " Angle Dekkor." This uses a reflecting cube with or without the aid of an optical square and in conjunction with adaptors and a special reading telescope mounted on a tripod. This special testing apparatus has an advantage inasmuch as it can make a series of these tests at the one set-up of the telescope ; also it does not depend upon the level of the machine table in the first instance. If it so happened that the machine had not been properly levelled up, you could still carry out your tests with the Hilger " Angle Dekkor."

Another point, regarding the deflection of the standard clock

gauge rods and pillars, I heartily agree with what Mr. Mallett said in this matter. They are often too slender for reliability in measurement. I was also on the look out, after reading the description of the bevel gauge to find how the cast iron bar was situated, but I was glad to see that the 2 in. dimension, and not the 1 in., constitutes the depth, as I have rather visualised it from reading the paper.

With regard to periods between successive overhauls on a machine tool, I very much doubt whether they would be equal as Mr. Mallett mentioned. Of course, he was only quoting round figures, but I would say, unless each overhaul amounted to a complete stripping and rebuilding with a large percentage of replacements, the more general experience would be with the duration between successive overhauls growing shorter, if the machine is not allowed to get below a certain standard, whatever that standard may be. In fact, the very reasons which the lecturer subsequently gave would influence that minimum standard and tend to raise it, so that automatically the periods would become shorter. I would refer you to another author, as quoted on pages 87 and 88 of Volume XVI of the Journal of this Institution.

These points are not in the nature of carping criticism and doubtless Mr. Mallett will have his answer ready for them ; also much has been left unsaid for those who can say it very much better than myself. I simply conclude by saying that Mr. Mallett has amply demonstrated his wealth of knowledge and applied experience in this particular branch of production engineering and I shall therefore await both his answers and further discussion with great interest.

MR. MALLETT : The test for concentricity of the bar in the spindle must, of course, be taken at two points, as shown on the slide, as the errors might cancel out if only one point is tested. I use the faceplate on milling machines where face cutters bolt on to the spindle spigot and the faceplate is bolted on the same spigot.

You get a similar case when testing a table slide for transverse travel, I have seen a clock gauge applied at one point and, because it did not move, the slide was supposed to be right, whereas it is essential to apply also the throw-over or trammel test from one side to the other side to ensure that not only is the side of the table parallel with the slide, but that it also runs square to the spindle. I have no experience with the " Angle Dekkor " but I can see its usefulness, particularly on large machines where very long straight edges would be required, and also where levels could not be used in the case where the machine is not level itself, as you mentioned. Also, on machines where there are two beds at right angles to a main column, it would be of service. Along the two right angled beds of such a machine you can swing it round and take your readings just like a surveyor surveys a field, quite similar, I think, to the use

of the Dekkor, only it is a much more precise instrument, because of the special method employed.

The lapse of time between overhauls does generally tend to decrease a little because, although you may decide on a complete overhaul, it is seldom economical to do it absolutely completely. For example, a screw may be only partly worn or gears slightly pitted, but the next time of overhaul is reached sooner because they and other parts have worn to the point of replacement. On the other hand, however, it is not always the case, as with the poorer class of machines they do actually last longer in the second period if you do the first overhaul properly. That is, if you look at it properly, go into details and effect improvements. For instance, if you do not have covered ways on the machine, you can at least put scrapers or wipers on the slides, whichever you think is better, put in better wearing gears and clutches, and so on. Convert the second class machine into as nearly as possible a first class machine for the second period, and the second period will be longer than the time during which it remained good enough from its date of purchase to the first overhaul. In your concluding remarks, you mentioned my wealth of experience. Everybody's experience is bound up in the knowledge of others. A lot of the things I have shown to-night have been observed and learned from the experience of other people. It was the gathering of them together which gave a little bit of work. That it has interested you is the main thing.

MR. P. J. D. FRASER : A great deal has been spoken to-night about discipline in the workshop, and in the factory. Mr. Mallett showed some very interesting slides about the carelessness that takes place in workshops, but often we are principally to blame if a man has not got a proper place for his spanners. For instance, if you give him a machine, six spanners, say, and one or two micrometers, but no place to put them except the work tray, he has not very much chance. The place I am at present connected with has a satisfactory system. In front of the work-tray there is a board for the spanners and even some of his tools, each having its appointed place and supported so that it can be easily lifted off. The board is painted green, and each tool is silhouetted on the board in yellow paint. Anyone inspecting the tools can see right away if any of them are missing, and it is a handy place to leave the tools. Mr. Mallett laid a great deal of emphasis on the type of man who ought to be in the millwright squad. He has to be a well educated and accurate workman. In most works, at the present time, the millwright is the most poorly paid, others often making £1 per week more than the millwright. Millwrights, as soon as they know there is a vacancy at the fitting bench, apply for it, because they can make more money. If millwrights have to be so highly trained, why not give them a higher wage ?

MR. MALLETT : I quite agree with Mr. Fraser about the spanners. As a matter of fact that was one of the things I had in my original notes to lay at the door of the machine-tool manufacturer. I still think that he should supply the place to keep them, and in such a way that they are fitted out in an orderly way, in the case of spanners, and the tool-tray should be another facility placed within easy reach of the man. Certainly some makers do give a space for them, and I mentioned the possibility of someone else oiling the machine instead of the operator. There is no place for the grease-gun. It gets lost ! Then time is lost. It is a good idea of Mr. Fraser's ; that board so painted that you can actually see whether all the spanners, etc. are there. With regard to millwrights and their pay. I do not know that I can discuss that at this meeting. I think they ought to be good men and they ought to be well paid. I do not know what you pay yours. That must be your responsibility.

MR. W. P. KIRKWOOD : I think Mr. Mallett has done very well in emphasising the point in regard to the bad design of the clock gauge stand that is bought in the usual way, and to illustrate this, I call to mind an incident which happened a year or two ago where the truth of a mandrel was in question. I was assured by the toolroom foreman that it was dead true. He invited me to see this and he had it nicely set up with a standard clock gauge equipment and clock reading to .0001 in. and with that particular stand the mandrel appeared to be true. I objected to the stand on principle, and sent for one such as Mr. Mallett has illustrated. When the same clock gauge was put on the heavy stand and tried on the same mandrel, the latter was .0003 in. off truth. For the job in question this .0003 in. was vital. The toolroom foreman was surprised and, needless to say, immediately got a proper clock gauge stand. Mr. Mallett also emphasised the need for, or I should say, the advantage gained by lapping spindles. He did not say why, and I would venture to explain that. One of the greatest advantages of lapping a spindle after grinding, as opposed merely to grinding it, is that the initial wear is reduced more appreciably and, where we want accuracy, we want the initial wear either reduced to a very small amount or eliminated altogether.

Some time ago we made some experiments on the relative initial wear of lapped and of really good ground surfaces on a spindle and under identical conditions the rate of wear for the initial stages of running were approximately .00015 in. for a lapped spindle against .00035 in. to .0004 in. for a ground spindle. After initial wear had taken place, the rate of wear decreased very rapidly. In other words, the curve of wear is practically flattened out, and I think that accounts for the good results obtained with lapping spindles.

In connection with the filtration of both lubricating oil and cutting oil on machines, I would like Mr. Mallett to say whether he has any

experience of a filter of the auto-clean type where there are a number of thin laminations and the oil is forced through these laminations. The beauty of that type of filter is that it cleans and removes the dirt. In any machine tool it could be quite easily arranged to obtain the movement from the drive. A fine gauze filter has the nasty habit of choking and cutting down your supply. I am sorry he did not emphasise the considerable benefit obtained in increased machine life by seeing that the forgings and castings are as clean as they can be. Even pickling or sandblasting under such conditions are regarded as an unwarranted expense, but I think if it could be properly tallied the expense is more than balanced by increased machine and tool life.

MR. MALLETT : The first two points you mention, Mr. Kirkwood, deals with examples I gave in the lecture and you have amplified them in a very useful way. With regard to the auto-clean laminated type of filter, I have not seen one used on a machine, but of its use in the ordinary car engine, and large aero-engines of 800 H.P. I have had satisfactory experience. To put it in the circulating pipe for the cutting oil on a machine tool should be quite feasible, and I do not see why it should not be used. I have made a note of it to look at it further. The suggestion that I missed the point with regard to clean parts going into machines is certainly one other item that I ought to have included, and one of the precautions to be observed.

MR. MUNRO : In Mr. Mallett's address great stress has been laid on maintenance of machine tools, but there is one important factor, namely, the countershaft. Can Mr. Mallett tell us what attention a countershaft gets in relation to the life of the machine ?

MR. MALLETT : Countershafts should be oiled as a matter of routine in the general way during the dinner-hour by men who go round, and when finished, start all over again, paying extra attention to countershafts that may be troublesome. Frequency of attention must depend on the type of bearing, particularly the bearings in the loose pulleys. If you need a new countershaft then fit the ball bearing countershaft ; you do not need to worry about it. In many cases, I think this is the best answer. Generally you will have to deal with what you have.

MR. MUNRO : The question of wooden pulleys ? Few people can afford ball bearing bearing countershafts.

MR. MALLETT : I cannot give you an exact figure as to the life of a countershaft against the rest of the machine. It certainly requires more frequent attention. I would not like to give you a percentage. It is a matter of experience based a good deal on the use to which the machine is put and how heavily the belts are loaded ; also the design of the countershaft. Any figures I might give would mean

nothing. I appreciate the point you have mentioned, but I still think a ball bearing countershaft is the answer in difficult cases.

MR. W. BUCHANAN: One point I would like to emphasise and that is the lubrication of the machine. I think Mr. Mallett mentioned it, but I sometimes consider that it is not given enough thought by machine tool makers. The instance I have in mind was a direct-drive motor, geared to the machine spindle, and in this case, there was automatic lubrication, but through dirt getting into the oil, it became choked up. I think the machine was cutting when the breakdown took place. How are you to make sure you are getting lubrication ? I really think the only way a machine tool should be oiled is by automatic lubrication to all points.

Another matter that has come up recently with us is the direction of movement of levers and tables. We have recently received a machine in which, when the lever was moved to the left, the table moved to the right. It was a new machine ! All the other machines in the group have lever movements corresponding with those of the tables. I think the machine tool makers should have a standard for all to follow, as such anomalies are likely to cause breakdowns.

With regard to the cleaning of parts, in one shop I know, the method they use is to have a fairly deep tank half filled with water and a layer of paraffin about 2 or 3 inches deep, the idea being that when you cleaned your parts, the dirt that went into the oil sank to the bottom of the water and the oil was kept clean. Where one is dealing with many new operators, as is the case with us, one can hardly keep the breakdowns in hand, apart from spending a lot of time in the periodic overhaul of other machines.

MR. MALLETT : Your question, Mr. Buchanan, on the lubrication of machines and the difficulty of seeing whether the automatic lubrication is reaching the desired point. In the case of the headstock and gear boxes, a sight glass is used. In out of the way places the maker usually runs copper piping to the ball bearings and shaft bearings, and so on. I do not think I can say I have had a lot of experience of trouble there. There is no reason why you should not put sight glasses in these runs of piping near the point of application. Movement of machine handles which go the wrong way. Why did you buy the machine ?

MR. BUCHANAN : We did not buy it that way, anyway.

MR. MALLETT : They should be standard, I agree.

MR. LANG : There is a British standard going through now.

MR. BUCHANAN : Write and let the machine tool makers know.

MR. LANG : I think most of them will have had the standards which have been put forward. It is past the stage of discussion and should have reached you.

MR. BUCHANAN : There are four machines in the range, and there are three correct and the other one the opposite way.

MR. MALLETT : Someone may have assembled it wrongly ! I have heard of a motor car, the first of a new model, with the steering gear assembled with wrong action, where you turned the wheel right and you went left ! You mention the schedule of overhauls and the difficulty of keeping to specified routine work owing to the machines being operated by new operators. That is a problem. I cannot solve it here. Mr. Wright suggested discipline and training and he was on the right lines.

MR. PRIDDLE : I must mention how much I enjoyed the paper and say there have been quite a number of useful points brought up. Concerning the remark Mr. Fraser made with regard to spanners and facilities for holding tools, one is quite convinced how inadequate these machine equipments are in general shops to-day. With regard to the tool failures, I would like to know Mr. Mallett's opinion. I don't think altogether it is the man's fault. I have been in a few shops where equipment for sharpening tools has been inadequate. First of all, I don't think that the grit of the stone is correct to give the man a good enough tool to carry out the work. The man takes the tools to the store and has them replaced immediately by the proper tools. Men to-day are pressed for production and the fact that they are using a bad tool is only keeping them back. Are men stupid enough actually to hold themselves back wilfully ? What can be done in order to assist a man where the machine is not motor driven and there is no ammeter ? It is very important to have an ammeter to guide the man. He should be instructed in the use of the ammeter employed. I would like to take up the point that Mr. White brought out, and ask Mr. Mallett if it would be cheaper for tool makers to carry out a repair with regard to a machine, and more efficiently than a maintenance department. I liked the tools shown on the screen, all very valuable, but how many firms in Glasgow have them ? Not a quarter of them, I am sure. They may have no clock gauge for accurate work. It is a big responsibility for these men. They have to get on with the work but would it not be more efficient for a machine tool maker to take the machine in hand when he has all the equipment to carry out the repair, and also to sell the tool when it is fit to be replaced and enable the firm to carry on with a higher production machine. I would like to know your mind on this matter.

MR. MALLETT : The mention you made of tool failure. I don't think the men wilfully run their machines with blunt tools. They may occasionally in the way Mr. Wright suggests do it out of pride with a view to saying how long a certain tool lasted, but the average workman does not do it by preference. If he is supplied with tools

sharpened by a properly organised department, by the Tool Store, for instance, which supplies duplicate tools, or even more, so that when one tool gets blunt he sends the blunt one back for resharpening and uses the duplicate supplied, you will allow him less excuse for using a blunt tool. In fact, you are safeguarding your own machine and your own production. If a shop has not got proper tool sharpening facilities, then the only remedy is to provide them. With regard to the ammeter on a motor driven machine, I think you are simply adding to the remarks I made. Proceeding to the question as to whether a machine can be overhauled more cheaply by the makers than yourselves, I would like to add also whether he can always do it better than you can yourself. Certain makers, " yes " ; they can do it better than you can do it. In some cases not so well. Seldom do they do it more cheaply judging by the prices I have seen. In the case of small shops with small facilities, you send the machine to them as the best alternative. In a larger shop where you can provide facilities, I still think it is worth doing yourself. For one thing, you can take your machine when you can get it. You have not got to send it away and wait many weeks for its return. You can also choose how much of the machine you wish to overhaul. Makers are inclined to do the whole lot. You can also put the final degree of accuracy on that part of the machine where you know it is wanted and, except for the small shop, I really think it is best to overhaul your own machines. Cost of equipment, you say, is serious. Dial gauges are not very expensive, squares, straightedges and surface tables are found in many shops ; not always in very good condition, but you can easily remedy this. Use the simple A. B. C. test to put them in good condition.

If you have to consider the very small shop which has not got facilities, and you cannot even afford to send the machine to the makers and you cannot even afford a clock gauge, you can still do good work if you use ingenuity and care. Many years ago we had a bad fire and we had to overhaul our own machines because nobody made them as we built them ourselves to special designs and the only instruments we had for truth, where to-day we would use clock gauges, were scribing blocks and you can work to a fine degree of accuracy even with a scribing block if you know how to " sing " it over a surface. Also with a scribing block you can use feelers as " Go " and " Not Go " gauges. Similarly if I were asked to examine a machine which someone was overhauling for me and I distrusted the clock gauge, it would have to come off. I would put a tubular trammel bar on with an inserted point and, by using three and four thou. feelers as " Go " and " Not Go " gauges at either end, would get practically as close as with a clock gauge, but the process would, of course, be more laborious. Except for the most precise machines or spindles, you can actually do this work without elabor-

ate equipment. It will take you longer, of course. Generally you must have squares and straight edges, if only for your toolroom work, which can be borrowed. We could talk a lot on this point of equipment but I hope these remarks will have helped a little.

MR. LANG : When we consider economy in machine replacement, Mr. White and I are very biased on the subject for very definite reasons—we want you to buy new machines. I do think, Mr. Mallett, if you consider the wear and tear allowances and obsolescence allowances, quite a good case could be made for certainly the bigger factories using new machines and disposing of the original machines when they are at the overhaul stage. There is one other point and that is, Mr. Mallett stresses very strongly the need of substantial bars. That, I think, is rather important in many of these testing instruments. We have found, for instance, in testing spindles where we have bars projectong from the spindle about 18 in. long that with solid bars the droop was very much greater than we realised and in cases of that kind we use hollow bars and put in blocks at the end. Also we carry that out in connection with jigs where we have overhung bars for boring. We find definitely that hollow bars are better than solid bars and easier for men to handle.